Fisheries and Oceans Canada | Pêches et Océans Canada
Science | Sciences

CSAS | **SCCS**

Canadian Science Advisory Secretariat | **Secrétariat canadien de consultation scientifique**

Research Document 2012/038 | **Document de recherche 2012/038**

Newfoundland and Labrador Region | **Région de Terre-Neuve et du Labrador**

A pre-COSEWIC assessment of White Hake (*Urophycis tenuis*) in Newfoundland and Labrador waters

Évaluation pré-COSEPAC de la merluche blanche (*Urophycis tenuis*) dans les eaux de Terre-Neuve-et-Labrador

Simpson, M.R., C.M. Miri, and L.G.S. Mello

Fisheries and Oceans Canada
Northwest Atlantic Fisheries Centre
Science Branch
P.O. Box 5667
St. John's, NL, Canada A1C 5X1

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

La présente série documente les fondements scientifiques des évaluations des ressources et des écosystèmes aquatiques du Canada. Elle traite des problèmes courants selon les échéanciers dictés. Les documents qu'elle contient ne doivent pas être considérés comme des énoncés définitifs sur les sujets traités, mais plutôt comme des rapports d'étape sur les études en cours.

Research documents are produced in the official language in which they are provided to the Secretariat.

Les documents de recherche sont publiés dans la langue officielle utilisée dans le manuscrit envoyé au Secrétariat.

This document is available on the Internet at:

Ce document est disponible sur l'Internet à:

www.dfo-mpo.gc.ca/csas-sccs

ISSN 1499-3848 (Printed / Imprimé)
ISSN 1919-5044 (Online / En ligne)
© Her Majesty the Queen in Right of Canada, 2012
© Sa Majesté la Reine du Chef du Canada, 2012

Canada

Correct citation for this publication:

Simpson, M.R., Miri, C.M., and Mello, L.G.S. 2012. A pre-COSEWIC assessment of White Hake (*Urophycis tenuis*) in Newfoundland and Labrador waters. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/038. ii + 59p.

ABSTRACT

This paper presents the most recent information on the biology, and trends in abundance and distribution, for the assessment of White Hake (*Urophycis tenuis*) in Newfoundland and Labrador waters. The primary purpose of this paper is to provide this information to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) for use in its evaluation of risk of extinction for this species. Based on genetic information, White Hake in NAFO Div. 3NOPs is considered distinct from other populations of White Hake in the Gulf of St. Lawrence and on the Scotian Shelf. In Newfoundland and Labrador waters, White Hake is at its northern boundary and found mostly in the warmest waters available along the continental shelf slope of the southwestern Grand Bank, and in the Laurentian and Hermitage Channels. Research vessel survey indices of White Hake abundance remained relatively stable through the time-series and persists mainly at low levels. However, trends in abundance indices from surveys also indicate the occurrence of high recruitment events, particularly in 1999-2000 that resulted in strong year-classes and increases in area of occupancy, as well as increases in reported commercial landings during the first half of the 2000s. Relative abundance quickly declined afterwards and is presently at levels comparable to estimates prior to the 1999-2000 recruitment event.

RÉSUMÉ

Le présent document présente les données biologiques les plus récentes ainsi que les tendances sur les plans de l'abondance et de la répartition relativement à l'évaluation de la merluche blanche (*Urophycis tenuis)* dans les eaux de Terre-Neuve-et-Labrador. Ce document vise surtout à communiquer cette information au Comité sur la situation des espèces en péril au Canada (COSEPAC), qui s'en servira pour évaluer le risque de disparition de cette espèce. Selon les données génétiques, la merluche blanche dans la division 3NOP de l'OPANO est considérée comme distincte des autres populations de merluche blanche qui se trouvent dans le golfe du Saint-Laurent et sur le plateau néo-écossais. Dans les eaux de Terre-Neuve-et-Labrador, la merluche blanche est à sa limite nord et se trouve principalement dans les eaux les plus chaudes que l'on retrouve le long de la pente du plateau continental du sud-ouest du Grand Banc, et dans les chenaux Laurentien et Hermitage. Les indices d'abondance de la merluche blanche, qui proviennent de relevés par navire de recherche, sont demeurés relativement stables au fil des séries chronologiques et se maintiennent principalement à des niveaux bas. Toutefois, les tendances des indices d'abondance provenant des relevés témoignent également de vagues de recrutement, particulièrement en 1999-2000, qui ont entraîné des classes d'âge abondantes et un agrandissement de la zone d'occupation, de même que des augmentations des débarquements commerciaux déclarés au cours de la première moitié des années 2000. L'abondance relative a diminué rapidement par la suite et son niveau actuel est comparable aux estimations effectuées avant les vagues de recrutement de 1999-2000.

INTRODUCTION

White Hake (*Urophycis tenuis*, Mitchill 1815) is a highly fecund demersal fish inhabiting Northwest Atlantic waters from Cape Hatteras to southern Labrador (Kulka et al. 2005*a*). Formerly an important commercial species in the Gulf of St. Lawrence (NAFO Division 4T) and the Scotian Shelf (Div. 4VWX and 5), White Hake stocks have declined in those regions, as well as in the Gulf of Maine in recent years (Bundy and Simon 2005; DFO 2005; NEFSC 2007). White Hake abundance on the Grand Bank and off southern Newfoundland (Div. 3LNOPs) has been quite variable during the 1970s, 1980s, and 1990s (Kulka and Miri 2007; Simpson and Miri 2009); characterized by short periods of peak abundance followed by rapid declines. Throughout the 2000s, White Hake in Div. 3NOPs persisted at stable low levels following a large recruitment event in 1999-2000, which subsequently declined due to overfishing (Kulka and Miri 2007).

Recently, White Hake has been scheduled by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) for assessment under the federal Species at Risk Act (SARA). COSEWIC is a non-government scientific advisory body that has been established to perform species assessments and provide scientific foundation for listing species under SARA. Fisheries and Oceans Canada, as a generator and archivist of data on marine species, provides COSEWIC with the best information available to ensure that an accurate assessment of the species can be undertaken. The primary purpose of this paper is to provide this information to COSEWIC for use in its evaluation of risk of extinction for White Hake in Newfoundland and Labrador waters of the Northwest Atlantic Ocean.

SPECIES BIOLOGY

White Hake is a gadoid fish of the Family Phycidae (Scott and Scott 1988). Other common names include Ling, Mud Hake, and Merluche Blanche (French). White Hake has been reported as far north as the waters of Iceland and Greenland (Scott and Scott 1988; Cohen et al. 1990; Collette and Klein-MacPhee 2002). Musick (1974) described the southern limit as being the deep waters off of Florida. However, White Hake is primarily distributed along the continental slope from Cape Hatteras to the southern Grand Bank, and in the waters of the Laurentian and Hermitage Channels (Kulka et al. 2005*a*). White Hake also occur in the Gulf of St. Lawrence, on the Scotian Shelf, and throughout the Bay of Fundy (Scott and Scott 1988). White Hake is only rarely observed north of the Grand Bank or south of Georges Bank.

The stock structure of White Hake in Canadian waters has been investigated by several studies (Clay et al. 1992; Fowler et al. 1996; Hurlbut et al. 1996; Hurlbut and Clay 1998), and the prevalent view considers the existence of several stocks with some geographic overlap. Most recently, Seibert and Ruzzante (2006) characterized a number of polymorphic micro-satellite loci which could be applied to investigate stock structure and geographic variation in White Hake. In a subsequent study, Zinck (2007) applied the identified loci to an examination of the population structure of White Hake in the Northwest Atlantic, and found that the population on the southern Grand Bank and southern Newfoundland region (Div. 3OPs) was isolated from populations in the Gulf of Saint Lawrence (Div. 4T), Scotian Shelf, and Bay of Fundy (Div.4WX). In the Newfoundland and Labrador region, White Hake has been assessed as a single population in NAFO Div. 3NOPs; although the fishery in Div. 3NO is managed by the Northwest Atlantic Fisheries Organization (NAFO; with information from Subdivision 3Ps), while Subdiv. 3Ps is managed by Canada.

With respect to reproduction, White Hake can potentially produce millions of eggs per individual. Their eggs are buoyant, and remain in the upper water layer where they are dispersed by ocean currents (Han and Kulka 2007). Pelagic larvae hatch at 2-4 mm, and have an extended juvenile stage (Markle et al. 1982; Fahay and Able 1989). These early life stages remain in the upper water layer for two to three months (depending on water temperature) prior to settlement (Markle et al. 1982; Lang et al. 1996; Han and Kulka 2007).

The biology of White Hake in Newfoundland waters (Div. 3NOPs) was summarized in previous assessments (Kulka et al. 2005*b*; Kulka and Miri 2007). Size at first spawning has been estimated to be 30 cm (Kulka and Simpson 2002). Petrov (1973) found size-age relationships in Div. 3O to be: age 3 at 32-38 cm, age 4-5 at 48-56 cm, age 6 at 66-74 cm, and age 7 at 66-74 cm. Maximum age of White Hake was reported to be 14-16 years by Petrov (1973), and 23 years by Beverton and Holt (1959).

Estimated length at 50% maturity (L_{50}) for White Hake males in 1988-1998 ranged between 37-46 cm, and between 43-70 cm and 46-61 cm (Div. 3OPs) for females (Kulka and Simpson 2002). For 1996-2008, Simpson and Miri (2009) reported that L_{50} for males ranged between 37-39 cm, and 52-56 cm for females in the same areas. However, Gorchinsky and Makeenko (2005) did not find gender-dependent differences for L_{50} in the southern Grand Bank area (Div. 3NO) over 2000-2004 (L_{50} = 54 cm for both sexes).

Spawning in the Newfoundland region is proposed to occur during spring or summer. Kulka et al. (2005*a*) reported on the occurrence of functionally mature White Hake in April and May on the Grand Bank, supporting the view that spawning occurs in spring. However, those data were limited, and summer spawning has been previously reported by Petrov (1973) and Cohen et al. (1990); although those studies were even more limited in terms of evidence of spawning.

The role of White Hake in its ecosystem has been the focus of several studies. Petrov (1973) found that White Hake preyed upon a variety of fish and planktonic crustaceans in southern Newfoundland waters (Div. 3OPs). Similar dietary preferences were observed in the Gulf of St. Lawrence (Coates et al. 1982) and in American waters (Chang et al. 1999). Musick (1974) reported that fish species, such as Atlantic Cod (*Gadus morhua*), Atlantic Herring (*Clupea harengus*), and flatfishes are dominant components of the White Hake diet. Conversely, White Hake are preyed upon by other congeners, Atlantic Cod, and other species of fish (Langton and Bowman 1980; Bowman et al. 2000). In addition, White Hake can constitute a large part of the diet of Grey Seals (*Halichoerus grypus*) and Harp Seals (*Phoca groenlandica*) in the Gulf of St. Lawrence (Hammill and Stenson 2002). Moreover, Benoit et al. (2011) suggest that predation by Grey Seals on White Hake in the southern Gulf of St. Lawrence has elevated adult natural mortality to an extent that it is responsible for an observed decline in White Hake abundance.

MATERIALS AND METHODS

SURVEYS

NL Region

Data used in this study were obtained from Canadian bottom trawl research surveys conducted on the continental shelves of Newfoundland and Labrador (NAFO Div. 2GHJ3KLMNOPs) in spring (1971-2011) and autumn (1977-2010), which included areas beyond Canada's Exclusive Economic Zone (EEZ; Fig. 1). The surveys employed a random stratified design based on depth intervals and location (latitude and longitude) and are designed to provide information on

abundance, distribution and area occupied by several demersal and benthic fish and invertebrate species. A summary of the survey design employed in the NL Region can be found in Doubleday (1981).

Spring surveys of the Grand Bank (NAFO Div. 3LNO) commenced in 1971 with the inclusion of Subdivision 3Ps (comprising the St. Pierre Bank) in 1972; autumn surveys in Div. 2J3K were conducted by the *Gadus Atlantica* between 1977 and 1994 (Table 1). Further fall surveys of the northern Grand Bank (Div. 3L) began in 1981, adding the southern Grand Bank (Divisions 3NO) in 1990. The St. Pierre Bank was not surveyed in autumn. Surveys were conducted by CCGS *Teleost* in 1995-2000, although CCGS *Wilfred Templeman* surveyed part of Div. 3K. In Div. 3L, surveys were conducted by the *A.T. Cameron* (1971-82 in spring) and CCGS *Wilfred Templeman* or its sister ship, CCGS *Alfred Needler* (1985-2000 in spring; 1983-2000 in fall). In recent years, CCGS *Teleost* surveyed a portion of Div. 3L. The fall survey was also extended into Div. 3NO in 1990 using CCGS *Wilfred Templeman*.

Several demersal fishing gears were deployed over the timeframe of the spring and fall surveys (Table 1): Yankee 41.5 bottom trawl in spring surveys until 1982; Engel 145 Hi-lift trawl in fall surveys for 1977-1994, and in spring surveys for 1983-1995; and Campelen 1800 shrimp trawl in fall of 1995 and spring 1996 to the present. While survey design remained constant, additional strata were included in recent years; along with modifications to some of the original strata (Bishop 1994). One notable recent change in the surveys was an addition of shallower (< 50 m) and deeper strata (> 700 m) after 1993; although tows at depths < 50 m were occasionally recorded in earlier years. Furthermore, no conversion factors exist for White Hake catchability by these different trawls; therefore, these time series are not directly comparable.

Prior to the stratified random survey design established in 1971, groundfish abundance was estimated using line transect surveys over a range of depths. These Canadian research surveys were conducted in 1946-1958 utilizing the *Investigator II* with a Yankee 36 otter trawl. In 1959-1970, this vessel was replaced by the *A.T. Cameron* with a Yankee 41.5 otter trawl.

An additional stratified random survey was conducted to evaluate juvenile groundfish in Div. 3LNO during 1985-1994 using a Yankee 41 shrimp trawl. As well, a near-surface trawl survey for young gadoid fish (International Young Gadoid Pelagic Trawl or IYGPT) was conducted during August-September (1996-2000) in Div. 2J3KLNO (Dalley and Anderson 1998). Both survey series comprise the only available indices of young White Hake relative abundance and distribution.

Other Surveys of Interest

Additional independent scientific surveys were conducted by other countries within or adjacent to the study area often using the same stratification scheme as applied by Canada. Waters adjacent to the Canadian EEZ were surveyed by Spain (Instituto Español de Oceanografía, Far Fishery Program Communication), covering the "Nose" and "Tail" of the Grand Bank in Div. 3LNO (González-Troncoso et al. 2011; Román et al. 2011), and the Flemish Cap in Div. 3M (Casas and González-Troncoso 2011). Surveys from 1997-2001 in Div. 3NO were completed by the Spanish research vessel *Playa de Menduiña* with a Pedreira trawl, and during 2002-2009 with the Spanish *Vizconde de Eza* equipped with a Campelen trawl. This research trawler was also used in Div. 3L for 2003-2004 and 2006-2010. In addition, surveys were conducted on the Flemish Cap (Div. 3M) during 1992-2003 with the RV *Cornide Saavedra* using a Lofoten trawl, and in 2004-2010 with the RV *Vizconde de Eza* using a Campelen trawl.

Russia and France have also conducted surveys in the study area.

Spatial distribution and habitat associations

Geo-referenced catch and hydrographic data for Canadian spring and fall bottom trawl surveys were used to assess spatial distribution and habitat associations of White Hake throughout the study area. First, maps of the geographic distribution of standardized catch rate (kg/tow) were plotted using data from available surveys. The plots were grouped by season and into two 5-year periods; except for the spring survey series during the 1990s, which were grouped into 1990-1995 and 1996-1999. The latter periods were chosen to correspond to changes in fishing gear types: i.e., from Engel to Campelen trawls over 1995-1996. In addition, recent years were plotted on an annual basis for comparison to long-term aggregate maps.

Distribution of catch in relation to depth and temperature was also investigated. During DFO-NL surveys, depth and bottom temperature were recorded at each tow location using trawl-mounted sensors (SIMRAD depth sounder; Seabird 19 CTD). Plots of mean catch rate in relation to tow depth and temperature were produced for each NAFO Division, year, and season.

Area of occupancy

The area of occupancy (A_t) was calculated in each year t as follows:

$$(4) \qquad A_t = \sum_{k=1}^{S} \sum_{j=1}^{N_k} \sum_{i=1}^{n_j} \frac{a_k}{N_k n_j} I \quad \text{where } I = \begin{cases} 1 \text{ if } Y_{ijkl} > 0 \\ 0 \text{ otherwise} \end{cases}$$

where Y_{ijkl} is the number of fish in length interval l caught in tow i at site j in stratum k, a_k is the area of the stratum k (km^2), N_k is the number of sites sampled in stratum k, n_j is the number of tows conducted at site j, and S is the number of strata.

Abundance indices and size composition

Abundance and biomass were estimated by areal expansion of stratified arithmetic mean catch per tow (Smith and Somerton 1981). Survey indices were expressed as mean fish number and weight (kg) per standard tow, and reported for spring (Div. 3LNOPs) and fall (Div. 2HJ3KLNO). Estimates of abundance at length for males and females were available for the spring time-series in Div. 3NOPs, and calculated as the sum of strata estimates for each length group over the survey area. Estimation was also done separately for juveniles and adults, and indices were expressed as numbers per tow. Kulka and Miri (2007) indicated that total length (TL) < 58 cm and ≥ 58 cm for White Hake from Div. 3NOPs correspond to juvenile and adult components of that population, respectively.

Maturity

Maturity information was recorded intermittently during 1996-2011 as part of DFO-NL research surveys. Maturity stages of both male and female White Hake are classified based on a scale developed for Atlantic Cod. Using the limited information available, a probit analysis was conducted to determine the length of 50% maturity (L_{50}) and create maturity ogives for White Hake in Div. 3NOPs on an annual basis.

COMMERCIAL FISHERIES REMOVALS

Commercial fishery removals of White Hake in NAFO Subareas 1-3 were examined for 1960-2011, using commercial data available from three data sources: the Northwest Atlantic Fisheries Organization STATLANT-21A White Hake catch data (1960-2011), reported by NAFO member countries fishing mainly outside Canada's 200-mile limit; DFO-NL ZIF (Zonal Interchange Format) White Hake landings data (1985-2011), recorded in logbooks by Canadian fishers operating in Canada's EEZ; and Canadian Fisheries Observers' catch and discards data (1978-2011prelim.), collected on a set-by-set basis in a standardized format on board commercial fishing vessels at sea. Data from 2011 are preliminary in all cases.

With NAFO-reported data, total reported catches of White Hake were calculated by year and NAFO Division. With DFO ZIF data, total reported landings of this species were calculated by year, Division, White Hake bycatch/directed fisheries, and fishing gear type. Fisheries Observers' discards data were prorated to ZIF total groundfish landings inside Canada's 200-mile limit to estimate annual discards of White Hake in Canada's EEZ. Annual discards were estimated by multiplying the total observed White Hake discards and ZIF total reported landings of all groundfish species, then dividing this estimate by the total observed catch of all groundfish species. Canadian Fisheries Observers also collected at sea commercial length measurements of this species by year, Division, and fishing gear type.

RESULTS

SPATIAL DISTRIBUTION AND HABITAT ASSOCIATIONS

Survey catch distribution

Recent annual (2007-2011) distributions of White Hake catch rates in Div. 3NO and Subdiv. 3Ps from Canadian spring research vessel surveys were consistent with aggregated historic distributions. Geographic distributions of catch rates indicated that White Hake were found mostly along the continental shelf slope of the southwestern Grand Bank (Div. 3O) based on spring and fall surveys, and in the Laurentian and Hermitage Channels (Div. 3P) based on spring surveys (Fig. 2, 3). Note that Subdiv. 3Ps is not surveyed in the fall. White Hake were captured only sporadically elsewhere on the Grand Bank (Div. 3LN) in both seasons, and in areas further north (Div. 2HJ3K) in fall.

These distribution patterns were to a large extent consistent through both spring and fall time-series, despite expansions in surveyed areas and changes in gear types and vessels over the years. Dense White Hake concentrations (> 40 kg/tow) were observed in the spring survey in Div. 3O and Subdiv. 3Ps during the late 1970s and 1980s, but high density tows declined through the 1990s in these areas, as catch rates were mostly < 10 kg/tow everywhere. There was an increase in the frequency of high density tows during 2000-2004, notably along the shelf edge in Div. 3O, but such a pattern was not evident during the later 2000s. Another spatio-temporal feature of survey catch rate was a seasonal difference in White Hake distribution: White Hake were more prevalent in fall than in spring in Div. 3N; particularly in shallower areas of the Southeast Shoal. Furthermore, White Hake in Div. 3O were present in shallower areas of the southwest slope of the Grand Bank in fall. It should be noted that some temporal differences in distribution were partially related to a change in research survey gear that occurred over 1995-1996 (from Engel to Campelen), and a higher efficiency of the Campelen trawl in capturing demersal and benthic fish of all sizes, especially smaller fish (Simpson and Kulka 2005;

Simpson et al. 2011). However, Han and Kulka (2007) indicate that juvenile White Hake are more prevalent on the shallower areas of the Grand Bank in fall when settling of young of the year fish tend to occur. Hence the observed seasonal differences in White Hake distribution patterns were confounded to some extent by changes in survey gear type and/or ontogenetic changes in behavior.

Distribution of survey catch rate in relation to depth showed that most large White Hake catches (> 100 kg/tow) occurred at depths ranging between 50-400 m in Div. 3N in spring and fall, and Subdiv. 3Ps in spring (Fig. 4). Mean catch rate peaked between 300-400 m in Div. 3O in both seasons (22-64 kg/tow), and between 400-600 m in Subdiv. 3Ps (30-42 kg/tow) in spring; whereas mean catch rates in the remaining areas (Div. 2J3KLN) were considerably lower (0.01-3 kg/tow), and peaked over a broader range of depths (100-1,300 m; Fig. 5). Seasonal differences in catch rates are also evident on the Grand Bank (Div. 3LNO). The depth range where White Hake are captured tends to be broader in spring (50-800 m) than in fall (< 400 m; Fig. 4). In most cases, mean catch rate peaked in deeper water (300-600 m) in spring and in shallower water in fall (200-500 m; Fig. 5). In addition, mean catch rates were substantially higher in deeper waters (> 500 m) during spring in Div. 3LNO starting in 1990 (when the fall survey was extended into Div. 3NO). Overall, the observed bathymetric patterns in catch rate distribution and ontogenetic behavioral changes (Han and Kulka 2007) suggest that the increased occurrence of White Hake over the Grand Bank during fall is due mainly to the settlement of juveniles on the shallower areas of the bank following their pelagic life stage.

Furthermore, distribution of mean catch rates in relation to mean temperature at tow depth showed that White Hake occurred in waters ranging from near 0 to 7°C, but that they are temperature seekers: catch rates were highest in the warmest waters (> 4°C) available through surveyed areas in Div. 2J3KLNO and Subdiv. 3Ps (Fig. 6). No seasonal differences in White Hake mean catch rates were observed in areas where comparisons are possible (Div. 3LNO).

Area of occupancy

Temporal trends in area occupied by White Hake in Div. 3NO and Subdiv. 3Ps show that A_t varied between 13-27% in all strata and between 3-19% (1000-7500 km^2) in Index strata (Fig. 7). Overall, the index fluctuated through the time-series, but the trend was upward since the early 1990s, peaking in 2006 between 19% (Index Strata) and 27% (all strata), and again fluctuating without a clear trend in more recent periods. A_t tended to increase through the 1990s in Div. 3NO in fall (all strata and Index Strata) and subsequently varied without a trend (all strata) or declined until 2009 (Index Strata; Fig. 8). Similar to the spring time-series, proportion of area occupied differed in fall: varying between 2-20% for all strata, and between 1-40% (< 1000-12000 km^2) for Index strata. Overall, area occupied by White Hake has been stable or increasing, while the small proportion of area occupied in most years reflects a restricted distribution of White Hake in Div. 3NO and Subdiv. 3Ps.

ABUNDANCE INDICES

Spring Survey Biomass and Abundance Indices

Due to the lack of a conversion factor between fishing gears utilized in DFO-NL spring and fall surveys, estimated indices of relative abundance and biomass for each gear type comprise separate time-series (i.e., not directly comparable). The spring survey covers all of the main areas where the majority of the stock is found (Div. 3NOPs) and thus can be used as the primary indicator of changes in abundance.

White Hake in Div. 3NOPs remained relatively stable throughout the three time-series; with the exception of a large recruitment event in 1999-2000 that subsequently declined (Fig. 9). Survey catch rates ranged mostly between 1-2 kg/tow (2-5 fish/tow) over 1971-1995, before increasing to the highest estimate of the three time-series in terms of catch weight (15 kg/tow) in 2000; then returning to a 1996-1998 level. Relative biomass increased rapidly in 1999-2000, then quickly declined, and is presently at levels comparable to earlier estimates within the Campelen time-series (Table 2a). During the Canadian spring survey of 2000, estimated abundance was 10-times greater than that observed in either the first years of the Campelen series or during recent years.

White Hake caught in DFO-NL spring surveys were between 14 cm to 101 cm in length. Partitioned by sex, White Hake numbers at length from Div. 3NO in 2005-2010 indicated that the peak of 16-28 cm (i.e., representing the Young-of-the-Year cohort, or YOY) observed in 2005 contained a majority of males, with only 16% females (Fig. 10). In addition, a small peak of 53-59 cm males was observed in 2005 (modes at 53 cm and 58 cm), with a smaller number of females ranging from 51 cm to 86 cm in length. The 2006 peak noted previously consisted of 58% males 33-45 cm long, and 42% females 36-47 cm in length. Furthermore, a small number of males ranged between 53 cm and 78 cm; while females were observed between 50 cm and 94 cm. In 2007, 51% of the relative abundance was male, while 49% was female (no peaks observed). A small number of White Hake 15-28 cm long was observed in 2008, containing 84% males and 16% females. In 2009, no fish < 26 cm were found, while a small peak of 58-61 cm males (mode of 59 cm) was predominant. The 2010 peak of fish 15-28 cm in length (noted previously) consisted of 62% males and 38% females. In Subdiv. 3Ps, 46% of the relative abundance in 2005 was male; with a main peak of 32-38 cm (main mode of 37 cm), and a small one at 55-61 cm (60 cm mode; Fig. 11). Females in 2005 were observed primarily in a peak at 39-47 cm (45-47 cm mode). Survey data were not available for spring 2006, due to mechanical difficulties aboard Canadian research vessels. In 2007, two peaks of females were evident: one at 44 cm in length, and another at 52-62 cm. Males comprised 37% of the 2007 survey results; with mainly 46-51 cm and 62-67 cm in length. Peaks of females were again observed in 2008: a small one at 30-32 cm, one at 37-45 cm, and a predominant one at 51-60 cm. Males constituted 41% of the 2008 results, with primarily 36-49 cm fish. In 2009, a peak of 19-28 cm was observed, containing 67% males and 33% females. This probable 2008 cohort was also found as juveniles in 2010, with 69% of all immature representing males at 29-39 cm (main mode at 38 cm), and 42% of all immature being females at 32-42 cm (main mode at 40 cm). Two other peaks of immature females were also observed that year at 45 and 49 cm.

Stage-based analysis of abundance from Canadian spring surveys in Div. 3NOPs for 1996-2010 indicated that immature White Hake (both sexes) comprised the dominant component (40-95%) of the population in most cases (Fig. 12), similar to what was observed for this stock in the years prior to 2000 (Kulka et al. 2005*b*). Peaks of male and female YOY were observed in 2000 (79-89%), whereas spawning stock abundance peaked in 2004 for females (43%) and 2007 for males (35%). Survey abundance indices (sexes combined; Fig. 13) of adult White Hake (> 54 cm TL), as compared to juveniles (1-53 cm TL), in Div. 3NOPs over 1996-2011 showed peaks of adults in 1999-2000 (4,550,000 and 5,669,000 fish, respectively); concomitant with the large recruitment event of 1999-2000. However, two subsequent peaks of adults in 2002 (5,653,000 fish) and 2004 (7,076,000 fish; the largest adult peak since 1996) did not result in any increases in juvenile abundance. Conversely, a small increase in White Hake juveniles observed in the spring 2011 survey (24,708,000 fish relative to a 7,995,000–average over 2003-2010) had occurred while adult abundance averaged 2,559,000 in 2008-2011 (i.e., similar to a pre-1999 abundance level of 2,121,000 adults). Overall the rate of decline in White Hake relative

abundance (Div. 3NOPs) during the period 1996-2011 was 26% for adults (rate of decline = $100.(1-e^{-\delta t})$, and δ is the slope from a regression line of $\log_e$ [abundance] and time).

Recruits per spawner expressed as the number of YOY males and females produced per adult female from spring surveys in Div. 3NOPs (1997-2010) were also highly variable prior to 2000 (1-49 fish/female), and relatively stable subsequently (1-2 fish/female; Fig. 14). Similarly, the overall number of White Hake recruits index varied widely from 1,000-100,000 recruits/year prior to 2000, but varied to a much lesser extent afterwards (500-2,000 recruits/year).

Autumn Survey Biomass and Abundance Indices

Estimated indices of White Hake biomass and abundance during fall (1990-2010) were available for Div. 3NO but excludes a significant portion of the stock in Subdiv. 3Ps (Fig. 15). Mean weight of White Hake caught per tow tended to increase since the mid 1990s (Campelen time-series), peaked in 2003 (3 kg/tow), then declined and fluctuated around 1 kg/tow, except in 2007 (2 kg/tow). Number of White Hake per tow fluctuated around 1 throughout the time-series, except in 1999 when this index substantially increased (21 fish/tow).

Relative biomass in these areas doubled and abundance increased by 10 times in 1999 (Table 2b), especially to levels never previously observed in Div. 3N. Survey biomass index then declined after 1999. The pattern of Campelen fall indices is offset by one year (i.e., earlier) as compared to that from spring surveys, because autumn surveys catch newly settled YOY that were spawned in the previous spring (Kulka et al. 2005*b*). About twenty-five weeks later, the next spring survey encounters the previous year's cohort as 1-year-olds. This pattern was most apparent when larger year classes were produced, such as in 1999. After 2003, biomass and abundance indices remained at levels similar to those observed in 1995-1998. Prior to 1995, the occurrence of White Hake in northern areas of Div. 2HJ3KL was sporadic. Following a survey gear change to a Campelen trawl, increased catchability of the latter gear was apparent, particularly with increased catch rates in Div. 3KL from 1999 to 2003 (Table 2b).

Juvenile Survey Biomass and Abundance Indices

Catch rates during Canadian juvenile groundfish surveys conducted in a portion of Div. 3LNO over 1985-1994 were highly variable during 1985-1991: ranging from 0.1-2.3 fish/tow, but remained at low levels (0.7-0.8 fish/tow) over 1992-1994 (Fig. 16).

Other Surveys of Interest

Other surveys that estimated White Hake biomass and abundance indices include EU-Spain surveys in the NAFO Regulatory Area (NRA) of Div. 3NO (Fig. 17). The EU-Spain biomass index, mean catch per tow, was highest in 2001 (5.2 kg/tow), declined to 2003 (0.8 kg/tow), increased to a small peak in 2005 (2.5 kg/tow), then declined to its lowest level in 2008 (<0.1 kg/tow); after which it was between 0.3-0.5 kg/tow in 2009-2010. This trend is similar to that observed by Canadian spring surveys, which covered all of Div. 3NO; although in absolute terms, the Canadian index was higher than the Spanish index for most of the time-series.

The above trends were also reflected in two other indices from Spanish and Canadian spring surveys: abundance at length (mean number per tow), and estimated biomass (Fig. 18). A 2005 peak observed by Spain consisted primarily of 52-71 cm White Hake with a mode at 58 cm, while a small peak of 14-27 cm fish (1-year-olds; as described by Kulka et al. 2005*a*) appeared with modes of 14, 20, and 26 cm. These Age-1 fish represented the 2004 cohort. In 2009, EU-

Spain observed a small peak of 59-65 cm fish with a mode of 65 cm, while a similar peak of 54-61 cm fish (mode of 58 cm) was found in the Canadian spring survey. In 2010, Canada observed a small peak of 15-27 cm fish (Age-1); representing the 2009 cohort. Biomass indices declined from 3,500 t in 2001 to 750 t in 2003, increased to 2,000 t in 2005, then decreased to the lowest estimate of this time-series in 2008 (< 100 t), prior to increasing to 400-600 t in 2009-2010 (Fig. 19). Biomass estimates based on the Canadian time-series were higher than the Spanish indices; even though temporal trends were mostly similar: from 15,000 t in 2001 to 4,000 t in 2007, then increasing to 7,000 t in 2011.

Maturity

Length at 50% maturity (L_{50}) was found to vary between sexes from Div. 3NOPs in 1996-2011 (Fig. 20). Males reached L_{50} at considerably smaller sizes (39 cm average) than females (54 cm average), with an apparent declining trend, suggesting that both sexes are becoming mature at smaller sizes in more recent periods. Cumulative distribution functions (ogives) depicting the annual variation in length at maturity for male and female White Hake confirm the latter trends; according to the ogives L_{50} tended to move towards smaller length-classes through the 1990s and 2000s for both males and females (Fig. 21).

COMMERCIAL FISHERIES REMOVALS

White Hake in Div. 3NO came under quota regulation in September 2004, when the Fisheries Commission of NAFO established a Total Allowable Catch (TAC) of 8,500 t for 2005-2007. This allocation was between Canada (2,500 t), the EU (5,000 t), Russia (500 t), and remaining NAFO member countries (500 t). This TAC was maintained at 8,500 t for 2008-2009. In September 2009, Fisheries Commission reduced the TAC of White Hake in Div. 3NO from 8,500 t to 6,000 t for 2010 and 2011.

NAFO-reported catches in the NRA of Subarea 2 and Div. 3KLMNOP show that between 67 and 98% (mean at 92%) of reported annual catch were from Div. 3NOPs prior to 1994, and between 12 and 97% (mean at 47%) thereafter (Table 3; Fig. 22); however, the latter resulted from an increase in the frequency of reported catch from undisclosed areas rather than a decline in catch from Div. 3NOPs. During the 1960s and 1970s an average of 899 t of White Hake was caught annually; with 42% caught in Div. 3O. A peak of 9,074 t was reported for 1971; with 74% caught in Div. 3O. In 1972-1986, annual catches averaged 4,763 t; with 56% caught in Div. 3O. A peak of 9,704 t was then reported for 1987; with 55% caught in Div. 3O. A 3,246 t average was reported over 1988-1993 (35% in Div. 3O), and a 4,628 t average in 1994-2001 (70% from undisclosed areas). The largest annual peaks reported since 1960 occurred in 2002 and 2003; with 10,181 t and 12,292 t, respectively. In 2004-2008, annual catches averaged 4,275 t; with 25% in Div. 3O, 31% in Div. 3P, and 38% from undisclosed areas. Furthermore, commercial removals of White Hake from undisclosed areas totaled 41,800 t for 1994-2007. By 2009-2010, total NAFO-reported White Hake catches in all areas combined averaged 776 t. Provisional data reported for January-August 2011 indicated a total catch of 143 t in the NRA.

Before Canada commenced a directed fishery for White Hake in 1988 in Div. 3NO of Canada's EEZ, landed bycatch of this species by Canadian fishers in all Divisions (combined) was reported as a 2,351 t average over 1985-87 (74% in Div. 3O; 24% in Div. 3N; Fig. 23, 24). In 1988-1993, an average of 1,628 t was reported annually (69% in Div. 3O; 27% in Div. 3N, which became insignificant after 1990). Reported landings decreased to a 556 t average in 1994-99 (55% in Div. 3P; 52% in Div. 3O); then increased to an annual average of 1,627 t in 2000-08

(63% in Div. 3P; 37% in Div. 3O). Annual landings since 2008 decreased to approximately 600 t (53% in Div. 3P; 47% in Div. 3O). Provisional Canadian landings reported for January-September 2011 totaled 230 t (73% in Div. 3P; 27% in Div. 3O).

Regarding fishing gears used in Canada's EEZ, Canadian fishers deployed primarily gillnets and longlines in 1994-2011; with reported landings of White Hake averaging 567 t and 497 t annually, respectively (Fig. 25). However, most of the average annual landings of 1,637 t reported for White Hake caught by Canadian hook and line gear from the mid 1980s to the early 1990s were actually Atlantic Cod; therefore, these data should be interpreted with caution. Whit respect to bottom trawls, White Hake landings remained relatively low (64 t average annually) in 1985-2011; except for three peaks of approximately 270 t reported in 1989, 1993, and 2002.

At-sea discard estimates collected by Canadian Fisheries Observers suggested that a 231 t average of White Hake was discarded annually in Canadian waters of Div. 3OP over 1985-1992 (Fig. 26). Discard estimates then decreased to an annual average of 53 t in 1993-2010; except for a 150 t peak observed in 2004.

Length frequencies taken in Canadian fisheries in Div. 3O during 2005-2008 by Fisheries Observers indicated that gillnets captured 32-104 cm fish (mode ~74 cm); and a smaller range of 45-99 cm fish (mode at 71-72 cm) were observed in 2009 (Fig. 27a; no samples taken in 2010). Canadian longlines in Div. 3O caught larger White Hake: with a range of 41-111 cm, and mean lengths of 83 cm, 75 cm, and 77 cm in 2007, 2008, and 2009, respectively (Fig. 27b; no samples taken in 2010). In Subdiv. 3Ps, Canadian longlines captured 39-105 cm fish; with mean lengths of 76 cm and 73 cm in 2008 and 2010, respectively (no samples taken in 2009).

Commercial catch of White Hake by Russian trawlers in the NRA of Div. 3NO in 2006-2007 contained 21-90 cm fish with a mean length of 53 cm (Fig. 28). In addition, Russia observed a peak of 24-36 cm White Hakes (mode at 27 cm) in 2006, and a main peak of 51-69 cm (mode at 63 cm) in the following year. Russia did not sample commercial White Hakes in 2008-2010. Portuguese trawl fisheries (130 mm mesh) in the NRA of Div. 3NO in 2006-2007 captured very similar White Hakes: 23-76 cm fish in 2006 (mean of 49 cm); and 26-65 cm fish in the following year (mean of 45 cm; main mode at 40 cm; Fig. 29). In 2008, EU-Portugal collected only one sample of 31 trawled fish (range: 38-58 cm; mean: 48 cm), which precludes any conclusions to be drawn from it. EU-Portugal captured similar sized fish in 2009 relative to earlier years; with a range of 29-67 cm, and a mode at 47 cm. In 2010, while a mode at 46 cm was similar to previous years catch in Div. 3O, the distribution of lengths was larger: ranging from 29 to 77 cm.

Relative fishing mortality (Rel. F = NAFO commercial catch/Canadian spring survey biomass) for White Hake in Div. 3NO and Div. 3NOPs declined to its lowest level in 1999-2002, increased to a high peak in 2003-2004, then declined to a level comparable to the mid 1990s (Fig. 30). Relative F was higher in Div. 3NO than in Subdiv. 3Ps during 2003-2004, because of new directed fisheries for White Hake by EU-Spain, EU-Portugal, and Russia; coupled with very low recruitment after 1999.

Commercial catch of White Hake by Canadian otter trawl and gillnet fisheries was distributed mainly in areas where research survey catches of this species occur (Fig. 31, 32): primarily along the Laurentian Channel, in the Hermitage Channel, and in the area of St. Pierre Bank and the southern Grand Banks in Div. 3NO and Subdiv. 3Ps. In addition, there are also reported clusters of White Hake catches in more northern areas (Div. 2HJ, Div. 3K) in both otter trawl and gillnet fisheries. However, the latter likely represents mis-identified Threebeard Rockling

(*Gaidropsarus ensis*), since White Hake are usually not reported in more northern areas (Kulka 2001; Kulka et al. 2007).

DISCUSSION

White Hake in Newfoundland and Labrador mainly inhabit the waters of the southern Grand Bank and St. Pierre Bank, which fundamentally represents the northern extent of its global range. Based on the most recent genetic information and other biological data, this population is considered distinct from other White Hake stocks in the Northwest Atlantic. While this species is highly fecund, spawner biomass has persisted mainly at low levels throughout the available time series. However, available abundance indices are characterized by rare episodic events when abundance peaks due to a very large year-class. Most recently, the spring index for Div. 3NOPs peaked in 2000, due to a very large 1999 year-class that declined afterwards due to increased fishing mortality and subsequent low recruitment. It is hypothesized that occasional favorable environmental conditions, combined with a highly fecund species such as White Hake, are responsible for these high recruitment years (Han and Kulka 2007). Since 2004, the stock has remained at a level of abundance similar to that observed in the mid 1990s. From 2002 to 2010, the population has exhibited little recruitment; as indicated by staged abundance analysis. While increases in White Hake spawner biomass in Div. 3NOPs will require a number of relatively strong year-classes that survive to maturity, it should be noted that there was a recent increase in relative abundance of both juveniles (mostly) and adults in Div. 3NOPs during the 2011 Canadian spring research survey (Fig. 13).

White Hake in Div. 3NO is currently under quota regulation. The TAC of White Hake in Div. 3NO has been established at 6,000 t for 2010 and 2011. Average catch of White Hake, which was at its lowest levels in 1995-2001 (455 t), increased to 6,752 t in 2002 and 4,841 t in 2003; following growth of the large 1999 year-class to commercially harvestable sizes; upon which fishing effort on this species drastically increased both inside and outside Canada's 200-mile limit. Therefore, any increase in White Hake spawner biomass in Div. 3NOPs will also require a number of relatively strong year-classes that survive to maturity without contravening increases in fishing mortality by either Canadian or international fishers.

ACKNOWLEDGEMENTS

We thank Fisheries and Oceans staff who participated in Canadian research surveys, Canadian Fisheries Observers who collected data and specimens aboard commercial vessels under difficult conditions over many years, and the Instituto Español de Oceanografia in Vigo (Spain) for data from Spanish research surveys of Div. 3LNO (in the NRA); thereby allowing us to estimate trends and examine various biological aspects of White Hake.

REFERENCES

Benoît, H.P., Swain, D.P., and Hammill, M.O. 2011. A risk analysis of the potential effects of selective and non-selective reductions in grey seal abundance on the population status of two species at risk of extirpation, white hake and winter skate in the southern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/033: iv + 30 p.

Beverton, R.J.H., and Holt, S.J. 1959. A review of the lifespans and mortality rates of fish in nature and their relation to growth and other physiological characteristics. *In* CIBA Foundation colloquia on ageing: the lifespan of animals (Vol. 5). *Edited by* G.E.W. Wolstenholme and M. O'Connor. J&A Churchill Ltd., London, UK. pp. 142-180.

Bishop, C.A. 1994. Revisions and additions to stratification schemes used during research vessel surveys in NAFO Subareas 2 and 3. NAFO Sci. Coun. Res. Doc. 94/043. 23p.

Bowman, R.E., Stillwell, C.E., Michaels, W.L., and Grosslein, M.D. 2000. Food of northwest Atlantic fishes and two common species of squid. NOAA Tech. Mem. NMFS-NE-155.

Bundy, A., and Simon, J. 2005. Assessment of the status of 4VWX5 White Hake, 2005. DFO Can. Sci. Advis. Sec. Res. Doc. 2005/081. 46p.

Casas, J.M., and González-Troncoso, D. 2011. Results from bottom trawl survey on Flemish Cap of June-July 2010. NAFO Sci. Coun. Res. Doc. 11/021.

Chang, S., Morse, W.W., and Berrien, P.L. 1999. Essential Fish Habitat Source Document: White Hake, *Urophycis tenuis*, Life History and Habitat Characteristics. NOAA Tech. Mem. NMFS-NE-136.

Clay, D., Ferguson, M.M., Hurlbut, T., and Stott, W. 1992. An allozyme survey of White Hake (*Urophycis tenuis*) from the southern Gulf of St. Lawrence. Can. Tech. Rep. Fish. Aquat. Sci. 1908. 12p.

Coates, L.J., Roff, J.C., and Markle, D.F. 1982. Freshwater components in the diet of the marine neustonic fish, *Urophycis tenuis* (Mitchill). Environ. Biol. Fishes 7: 69-72.

Cohen, D.M., Inada,T., Iwamoto, T., and Scialabba, N. 1990. FAO species catalogue (Vol. 10): Gadiform fishes of the world (Order Gadiformes). An annotated and illustrated catalogue of cods, hakes, grenadiers and other gadiform fishes known to date. FAO Fisheries Synopsis No.125. Rome, Italy. 442p.

Collette, B.B., and Klein-MacPhee, G. (*eds.*). 2002. Bigelow and Schroeder's fishes of the Gulf of Maine (3rd ed.). Smithsonian Institution Press, Washington D.C. xxxiv + 748 p.

Dalley, E.L., and Anderson, J.T. 1998. Plankton and nekton of the northeast Newfoundland Shelf and Grand Banks in 1997.CSAS Res. Doc. 98/121.

DFO 2005. White Hake in the Southern Gulf of St. Lawrence (Div. 4T). DFO Can. Sci. Advis. Sec., Sci. Advis. Rep. 2005/009. 6p.

Doubleday, W.G. 1981. Manual on groundfish surveys in the Northwest Atlantic. NAFO Sci. Counc. Studies 2. 55p.

Fahay, M.P., and Able, K.W. 1989. White hake, *Urophycis tenuis*, in the Gulf of Maine: spawning seasonality, habitat use, and growth in young of the year and relationships to the Scotian Shelf population. Can. J. Zool. 67: 1715-1724.

Fowler, M., Black, J., Mohn, B., and Sinclair, M. 1996. 4VWX and 5Zc white hake 1996 stock assessment. DFO Atl. Fish. Res. Doc. 96/103.

González-Troncoso, D., González, C., and Paz, X. 2011. Biomass and length distribution for Roughhead grenadier, Thorny skate and White hake from the surveys conducted by Spain in NAFO 3NO. NAFO Sci. Coun. Res. Doc. 11/007.

Gorchinsky, K.V., and Makeenko, G.A. 2005. Preliminary results from Russian surveys and fishery of White Hake, *Urophycus tenuis*, in Divisions 3NO in 2000-2004. NAFO Sci. Coun. Res. Doc. 05/021.

Hammill, M.O., and Stenson, G.B. 2002. Estimated consumption of Atlantic cod (*Gadus morhua*) and some other prey by grey seals (*Halichoerus grypus*) and harp seals (*Phoca groenlandica*), in the southern Gulf of St Lawrence (NAFO Division 4T). DFO Can. Sci. Advis. Sec. Res. Doc. 2002/054.

Han, G., and Kulka, D.W. 2007. Dispersion of eggs, larvae and pelagic juveniles of white hake (*Urophycis tenuis*, Mitchill 1815) on the Grand Banks of Newfoundland in relation to subsurface currents. NAFO Sci. Coun. Res. Doc. 07/021.

Hurlbut, T., and Clay, D. 1998. Morphometric and meristic differences between shallow and deep-water populations of white hake (*Urophycis tenuis*) in the southern Gulf of St. Lawrence. Can. J. Fish. Aquat. Sci. 55(10): 2274-2282.

Hurlbut, T., Nielsen, G., Morin, R., Chouinard, G., and Hebert, R. 1996. The status of white hake (*Urophycis tenuis*, Mitchill) in the southern Gulf of St. Lawrence (NAFO Division 4T) in 1995. DFO Atl. Fish. Res. Doc. 96/041.

Kulka, D.W. 2001. Distribution of Greenland Halibut and by-catch species that overlap the 200-mile limit spatially and in relation to depth – effect of depth restrictions in the fishery. NAFO Sci. Coun. Res. Doc. 01/40.

Kulka, D.W., and Miri, C.M. 2007. The status of White Hake (*Urophycis tenuis*, Mitchill 1815) in NAFO Divisions 3N, 3O, and Subdivision 3Ps. NAFO Sci. Coun. Res. Doc. 07/052. 52p.

Kulka, D.W., and Simpson, M.R. 2002. The status of white hake (*Urophycis tenuis*) in NAFO Divisions 3L, 3N, 3O and Subdivision 3Ps. DFO Can. Sci. Advis. Sec. Res. Doc. 2002/055.

Kulka, D.W., Miri, C.M., and Simpson, M.R. 2005*a*. Distribution and aspects of the life history of White Hake (*Urophycis tenuis*, Mitchill 1815) on the Grand Banks of Newfoundland. NAFO Sci. Coun. Res. Doc. 05/060. 40p.

Kulka, D.W., Miri, C.M., and Simpson, M.R. 2005*b*. The status of White Hake (*Urophycis tenuis*, Mitchill 1815) in NAFO Divisions 3L, 3N, 3O and Subdivision 3Ps. NAFO Sci. Coun. Res. Doc. 05/066. 55p.

Kulka, D.W., Miri, C.M., and Thompson, A.B. 2007. Identification of Wolffish, Hake and Rockling in the Northwest Atlantic. NAFO Sci. Coun. Stud. 40.

Lang, K.L., Almeida, F.P., Bolz, G.R., and Fahay, M.P. 1996. The use of otolith microstructure in resolving issues of first year growth and spawning seasonality of white hake, *Urophycis tenuis*, in the Gulf of Maine-Georges Bank region. Fish. Bull. 94: 170-175.

Langton, R.W., and Bowman, R.E. 1980. Food of fifteen northwest Atlantic gadiform fishes. NOAA Tech. Rep. NMFS SSRF-740. 23 p.

Markle, D.F., Methven, D.A., and Coates-Markle, L.J. 1982. Aspects of spatial and temporal co-occurence in the life history stages of the sibling hakes, *Urophycis chuss* (Walbaum 1792) and *Urophycis tenuis* (Mitchill 1815) (Pisces: Gadidae). Can. J. Zool. 60: 2057-2078.

Musick, J.A. 1974. Seasonal distribution of sibling hakes, *Urophycis chuss* and *U. tenuis* (Pisces: Gadidae) in New England. Fish. Bull. 72(2): 481-495.

NEFSC [Northeast Fisheries Science Center] 2007. 44th Northeast Regional Stock Assessment Workshop (SAW-44) assessment summary report. Stock Assessment Review Committee (SARC), NOAA/Northeast Fish. Sci. Cent. Ref. Doc. 07-03. 66p.

Petrov, V.N. 1973. Maturity, feeding and length and age composition of White Hake, *Urophycis tenuis* (Mitch.) in ICNAF Subarea 3, 1969-72. ICNAF Res. Doc. 73/39: 101-104.

Román, E., González-Iglesias, C., and González-Troncoso, D. 2011. Results for the Spanish survey in the NAFO Regulatory Area of Division 3L for the period 2003-2010. NAFO Sci. Coun. Res. Doc. 11/019.

Scott, W.B., and Scott, M.G. 1988. Atlantic Fishes of Canada. Can. Bull. Fish. Aquat. Sci. 219: xxx + 731 p.

Seibert, J., and Ruzzante, D.E. 2006. Isolation and characterization of eight microsatellite loci for White Hake (*Urophycis tenuis*). Mol. Ecol. Notes 6: 924-926. doi:10.1111/j.1471-8286.2006.01401.x

Simpson, M.R., and Kulka, D.W. 2005. Development of Canadian research trawl gear conversion factors for Thorny Skate on the Grand Banks based on comparative tows. NAFO Sci. Coun. Res. Doc. 05/049. 13p.

Simpson, M.R., and Miri, C. 2009. An assessment of White Hake (*Urophycis tenuis*, Mitchill 1815) in NAFO Divisions 3N, 3O, and Subdivision 3Ps. NAFO Sci. Coun. Res. Doc. 09/028. 27p.

Simpson, M.R., Miri, C., and Mello, L.G.S. 2011. An assessment of White Hake (*Urophycis tenuis*, Mitchill 1815) in NAFO Divisions 3N, 3O, and Subdivision 3Ps. NAFO Sci. Coun. Res. Doc. 11/022. 28p.

Smith, S.J., and Somerton, G.D. 1981. STRAP: A user-oriented computer analysis system for groundfish research vessel survey data. Can. Tech. Rep. Fish. Aquat. Sci. 1030: iv + 66 p.

Zinck, J.W.R. 2007. Estimated population structure of white hake, *Urophycis tenuis* in the Northwest Atlantic Ocean using microsatellites. M.Sc. thesis, Department of Biology, Dalhousie University, Halifax, N.S. 51p.

Table 1. List of bottom trawl research surveys conducted in the Newfoundland and Labrador Region (NAFO Div. 2HJ3KLMNOPs) during the period 1971-2011. Various vessels and fishing gears were used over the years. Vessels: A.T. Cameron, Gadus Atlantica, Wilfred Templeman, Alfred Needler, and Teleost. Survey gear: Yankee 41.5 otter trawl (brown), Engel 145 otter trawl (blue), and Campelen 1800 shrimp trawl (yellow). White cell: no survey was conducted in the area/season/year. Winter/fall surveys (*).

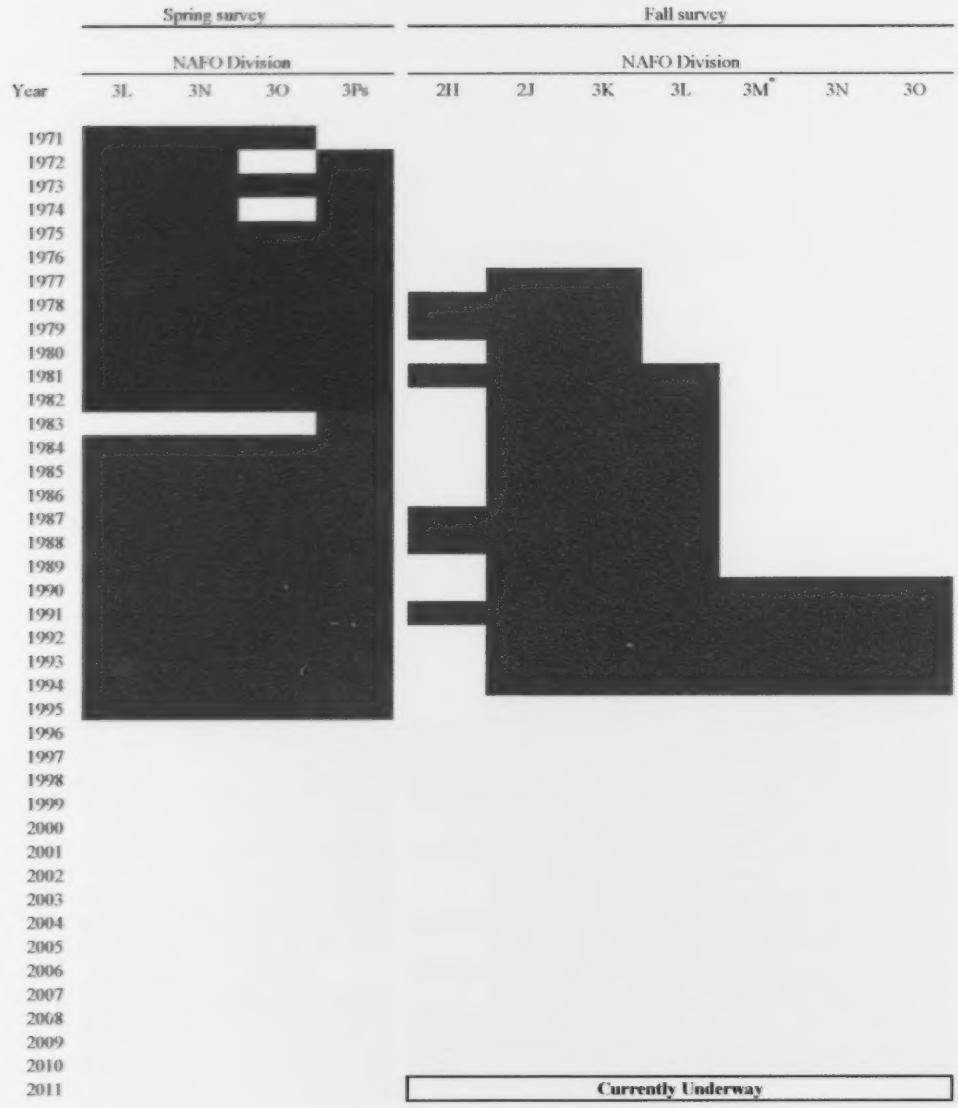

Table 2a. Biomass and abundance of White Hake from Canadian Spring research vessel surveys, 1971-2011. Surveys were conducted with a Yankee bottom trawl (1971-1983), an Engel trawl (1984-Spring 1995), and a Campelen trawl (Spring 1996-2011). NAFO Subdiv. 3Ps was not surveyed in 1971, 2006; NAFO Div. 3O was not surveyed in 1971, 1972, 1974, 1983; and NAFO Div. 3N was not surveyed in 1983. Note that deep strata in Div. 3NO were not surveyed in Spring 2006.

	Biomass (tonnes)				Abundance ('000s)			
Year	Div. 3L	Div. 3N	Div. 3O	Subdiv. 3Ps	Div. 3L	Div. 3N	Div. 3O	Subdiv. 3Ps
Yankee series								
1971	0	0	0		0	0	0	
1972	0	354		2,725	0	61		1,556
1973	0	36	1,532	465	0	11	327	247
1974	0	0		5,224	0	0		2,055
1975	0	0	3,173	4,491	0	0	1,080	2,646
1976	0	110	5,623	4,778	0	32	1,413	3,856
1977	0	50	1,339	7,168	0	43	466	3,935
1978	0	0	6,188	6,774	0	0	4,362	4,058
1979	0	165	1,978	6,310	0	34	1,065	3,078
1980	0	0	1,385	3,970	0	0	1,015	2,053
1981	0	139	96	7,448	0	29	93	4,743
1982	0	0	1,058	4,283	0	0	400	1,340
1983				2,539				1,508
Engel series								
1984	0	258	3,531	2,558	0	57	1,085	1,179
1985	0	47	2,878	5,303	0	9	1,315	3,045
1986	0	356	2,438	11,105	0	70	574	4,186
1987	0	44	2,752	9,866	0	95	1,114	4,438
1988	0	32	5,432	13,005	0	63	690	5,533
1989	0	0	925	6,884	0	0	252	4,130
1990	0	0	754	3,988	0	0	236	2,941
1991	0	0	1,039	4,591	0	0	1,118	3,800
1992	0	0	606	3,008	0	0	574	2,699
1993	0	0	522	2,929	0	0	301	2,670
1994	0	0	1,079	2,433	0	0	886	2,274
1995	0	0	334	2,334	0	0	189	2,104
Campelen series								
1996	0	4	2,020	6,282	0	75	2,982	8,089
1997	0	4	2,221	8,507	0	91	2,987	12,432
1998	0	7	2,205	4,007	0	79	2,249	4,765
1999	0	20	12,194	8,236	0	29	26,010	8,654
2000	0	30	15,900	10,294	0	716	104,360	11,743
2001	0	269	14,908	8,092	0	517	39,384	13,792
2002	0	96	10,808	10,118	0	105	11,334	15,098
2003	0	234	7,981	5,762	0	176	7,250	6,904
2004	0	33	10,369	6,622	0	53	8,477	6,977
2005	4	20	5,932	5,249	40	36	9,725	5,506
2006	4	247	12,267		25	69	10,370	
2007	0	2	3,510	6,940	0	7	2,734	6,061
2008	0	108	4,660	3,633	0	23	5,689	3,991
2009	14	184	4,656	2,582	45	152	2,804	4,547
2010	0	52	4,283	3,739	0	30	5,085	5,285
2011	6	571	6,423	4,727	68	2,175	17,834	6,745

Table 2b. Biomass and abundance of White Hake from Canadian Autumn research vessel surveys in Div. 3NO, 1990-2010. Surveys were conducted with an Engel trawl (1990-Autumn 1994), and a Campelen trawl (Autumn 1995-2010). Note that deep strata in Div. 3NO were not surveyed in 2003, 2004, 2006, and strata deeper than 730 m in the survey area were not surveyed in 2008.

Year	Biomass (tonnes)					Abundance ('000s)				
	Div. 2J	Div. 3K	Div. 3L	Div. 3N	Div. 3O	Div. 2J	Div. 3K	Div. 3L	Div. 3N	Div. 3O
Engel series										
1977	0	0	0	0	0	0	0			
1978	0	1	0	0	0	0	15			
1979	0	0	0	0	0	0	0			
1980	0	0	0	0	0	0	0			
1981	7	0	0	0	0	14	0	0		
1982	0	0	0	0	0	0	0	0		
1983	0	0	0	0	0	0	0	0		
1984	0	0	0	0	0	0	0	0		
1985	0	0	0	0	0	0	0	0		
1986	0	0	0	0	0	0	0	0		
1987	0	0	0	0	0	0	0	0		
1988	0	4	0	0	0	0	18	0		
1989	0	0	0	0	0	0	0	0		
1990	0	0	0	0	1,784	0	0	0	0	863
1991	0	0	0	0	2,805	0	0	0	0	2,047
1992	0	0	0	22	471	0	0	0	63	448
1993	0	0	0	0	748	0	0	0	0	490
1994	0	0	0	0	1,445	0	0	0	0	1,341
Campelen series										
1995	0	1	0	94	4,099	0	27	0	306	5,409
1996	0	1	0	6	3,960	0	28	0	143	3,850
1997	0	0	0	72	4,192	0	0	0	66	5,361
1998	0	0	1	171	2,896	0	0	15	2,036	5,079
1999	1	4	11	3,028	4,043	31	54	96	83,220	11,583
2000	0	5	3	1,165	9,551	0	214	37	2,875	22,750
2001	2	14	8	946	10,740	48	145	127	1,077	18,207
2002	0	12	4	2,753	11,384	0	161	39	2,126	13,434
2003	2	11	5	906	13,374	25	465	85	748	10,628
2004	0	10	3	1,847	2,237	0	143	30	2,084	1,492
2005	0	10	19	539	4,739	0	43	83	109	4,001
2006	0	2	6	212	2,086	0	27	49	98	2,288
2007	0	0	19	276	10,337	0	0	94	543	7,859
2008	9	0	0	620	2,557	138	0	0	415	2,426
2009	0	10	14	132	4,189	0	35	97	73	4,123
2010	0	0	3	630	3,695	0	0	34	2,508	3,465

Table 3. NAFO STATLANT-21A reported catches of White Hake in 1960-2010 by NAFO Division.

Year	Div. 2J	Div. 3K	Div. 3L	Div. 3N	Div. 3O	Div. 3P_total	Unknown Location
1960		4	31	201	391	732	
1961			1	26	177	140	
1962			911	3	1,790	96	
1963			2	12	134	115	
1964			10	14	113	142	
1965				130	46	153	
1966			10	13	153	84	
1967		107	4	573	1,001	190	
1968			25	5	86	556	
1969	5		9	10	56	583	
1970	12		4	69	151	807	
1971			33	498	6,694	1,841	
1972	4	15	25	293	3,592	2,472	
1973		33	144	92	2,815	1,617	
1974			33	245	2,834	1,492	
1975	13	21	46	1,229	4,356	2,256	
1976	1		477	900	2,497	1,463	
1977	4	1	44	1,027	2,071	1,805	
1978	1	1	9	712	1,881	1,227	
1979	1	5	17	290	1,279	895	
1980	3	3	15	451	2,167	690	
1981		4	9	831	874	1,160	
1982	1	8	12	692	1,249	896	
1983	1	1	25	301	2,595	508	
1984		2	6	508	3,827	805	
1985		20	41	1,652	4,507	1,219	
1986	1		138	867	3,738	1,299	
1987		92	85	5,340	2,721	1,410	
1988		35	138	1,696	1,065	761	
1989	1		101	883	1,126	731	
1990	1		82	1,060	1,060	1,454	
1991			46	1,527	960	1,524	
1992			34	19	1,647	1,324	
1993				18	1,004	985	
1994			4	36	257	676	4,737
1995			18	5	277	479	4,333
1996			104	28	312	442	3,287
1997			128	92	335	324	2,219
1998			255	81	196	570	2,364
1999			171	94	335	609	2,632
2000			295	145	422	1,170	2,985
2001			252	91	542	1,071	3,488
2002			283	1,221	4,146	970	3,255
2003			198	2,688	3,470	1,318	4,434
2004			193	176	1,739	1,460	3,525
2005	2	0	89	21	943	1,683	2,719
2006			71	75	1,128	1,500	1,704
2007			36	22	701	1,290	118
2008			63	32	838	710	66
2009			13	22	459	388	57
2010				13	198	400	0

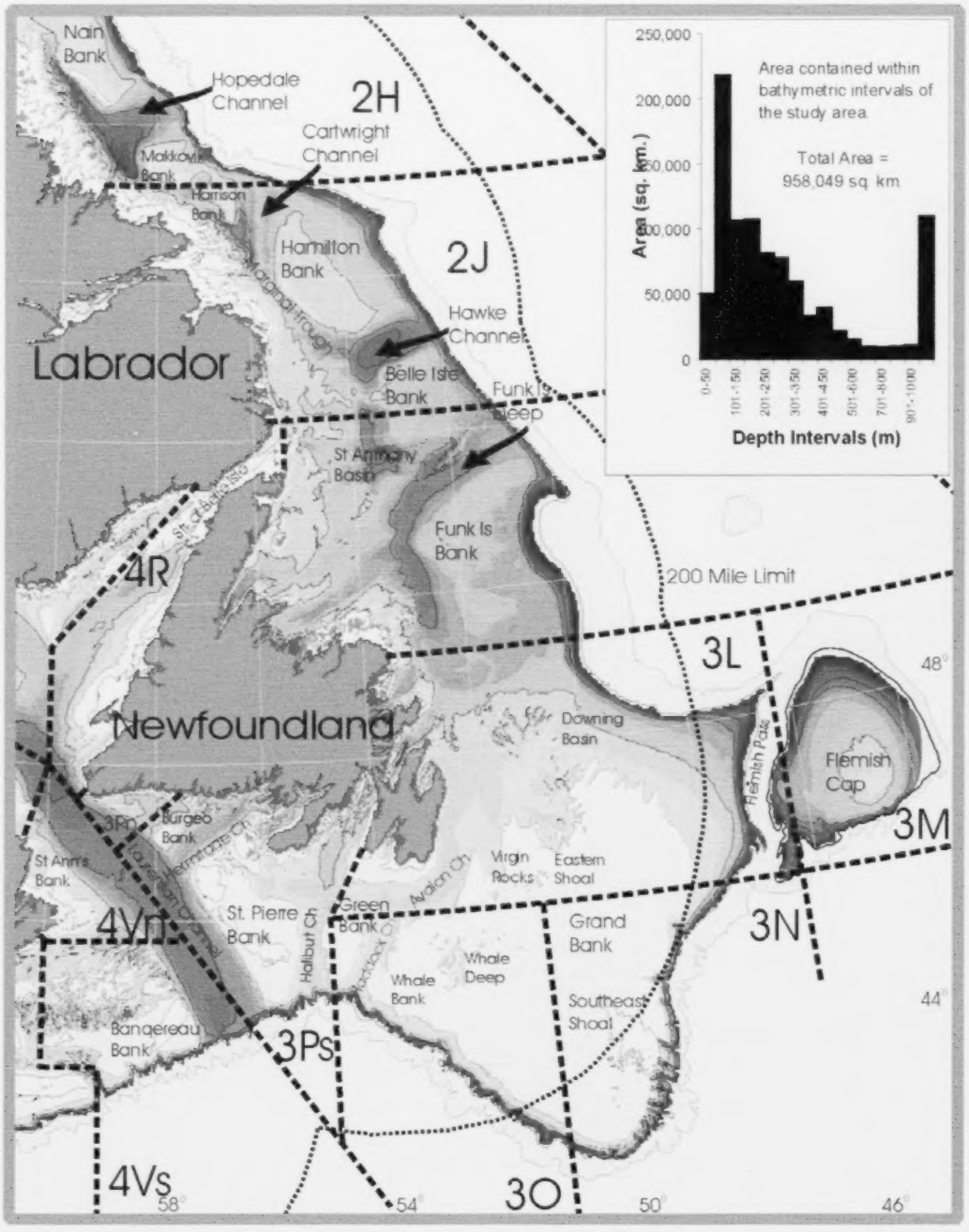

Figure 1. Map of the continental shelf off Eastern Canada and geographic features mentioned in the text. Depth range: < 100 m (light grey) to > 1000 m (dark grey). Canada's 200-Mile Limit is delineated by a fine dotted line and NAFO Divisions by coarse dotted lines.

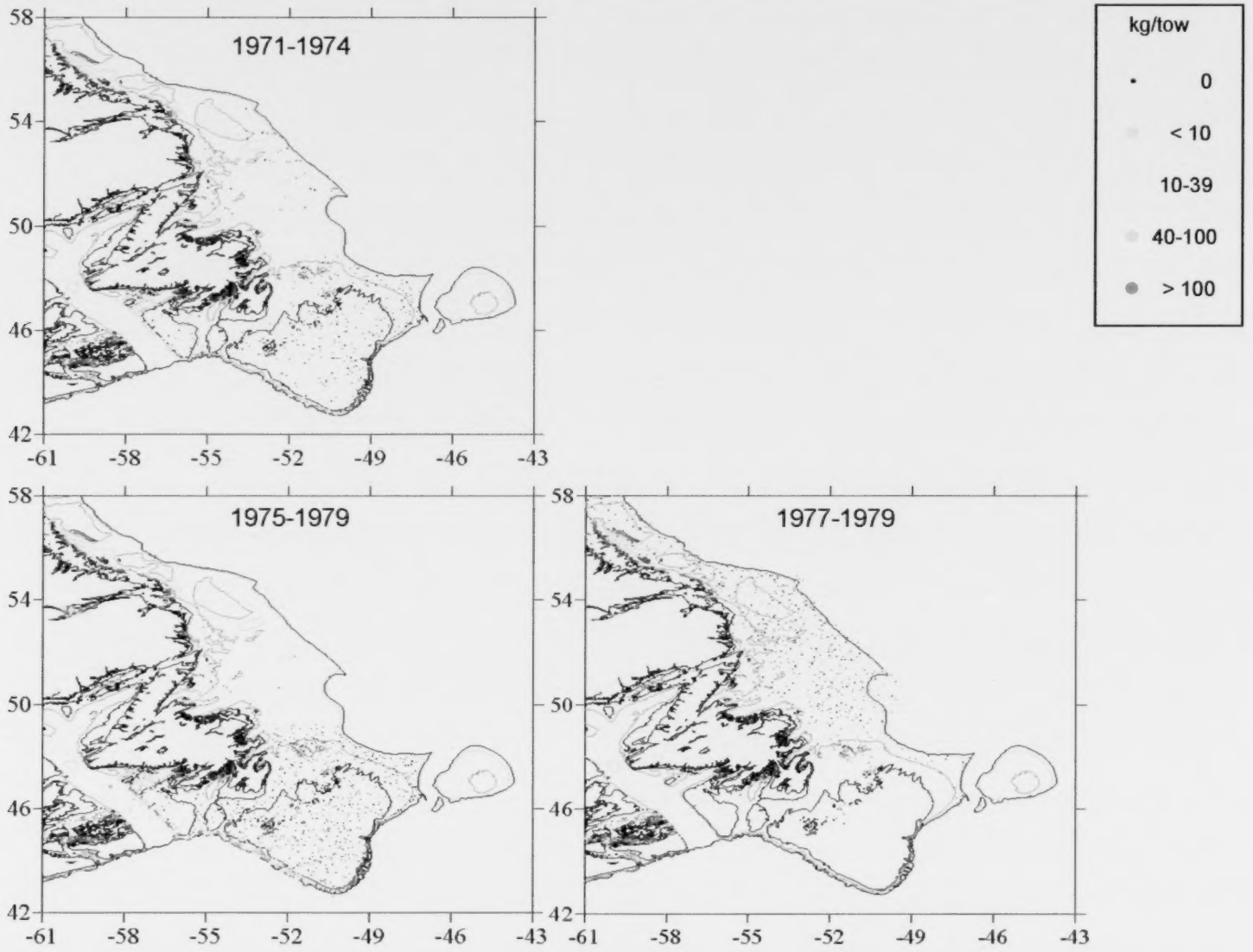

Figure 2. Geographic distribution of spring (Left Panels) and fall (Right Panel) Canadian research survey catch rates (kg/tow) for White Hake in NAFO Div. 2GHJ3KLMNO and Subdiv. 3Ps. Note that Subdiv. 3Ps was not surveyed in the fall.

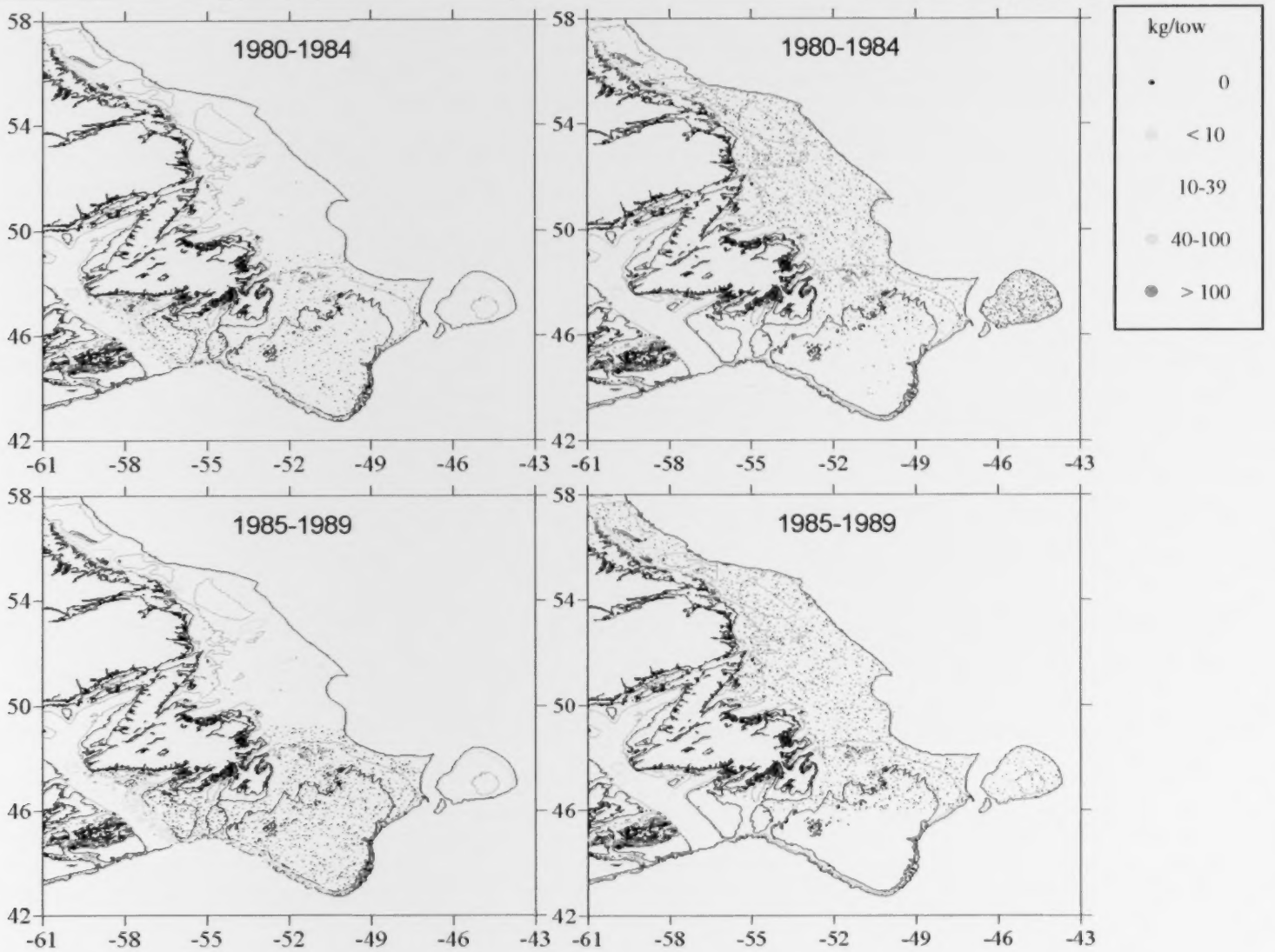

Figure 2 (cont.). Geographic distribution of spring (Left Panels) and fall (Right Panels) Canadian research survey catch rates (kg/tow) for White Hake in NAFO Div. 2GHJ3KLMNO and Subdiv. 3Ps. Note that Subdiv. 3Ps was not surveyed in the fall.

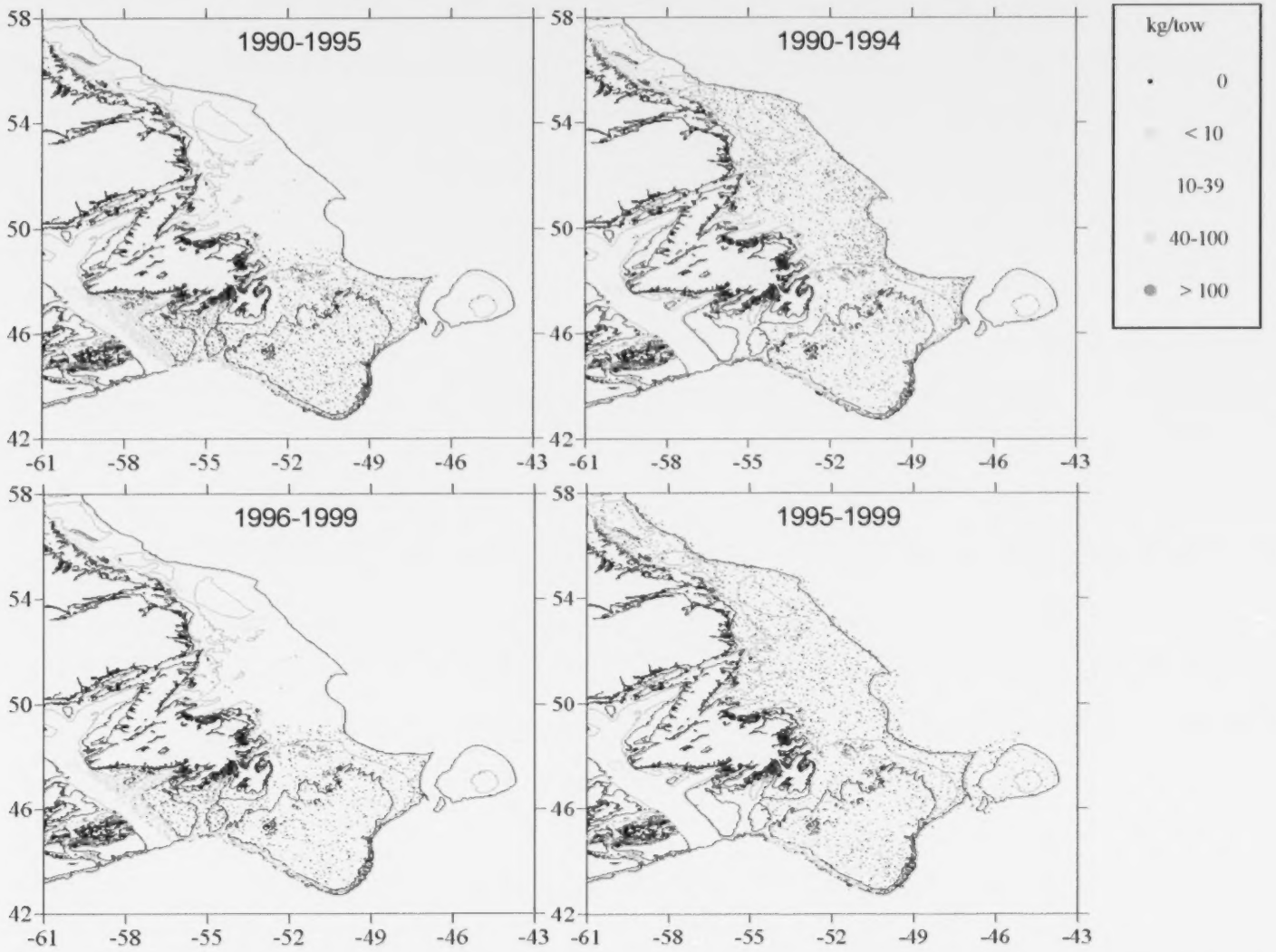

Figure 2 (cont.). Geographic distribution of spring (Left Panels) and fall (Right Panels) Canadian research survey catch rates (kg/tow) for White Hake in NAFO Div. 2GHJ3KLMNO and Subdiv. 3Ps. Note that Subdiv. 3Ps was not surveyed in the fall.

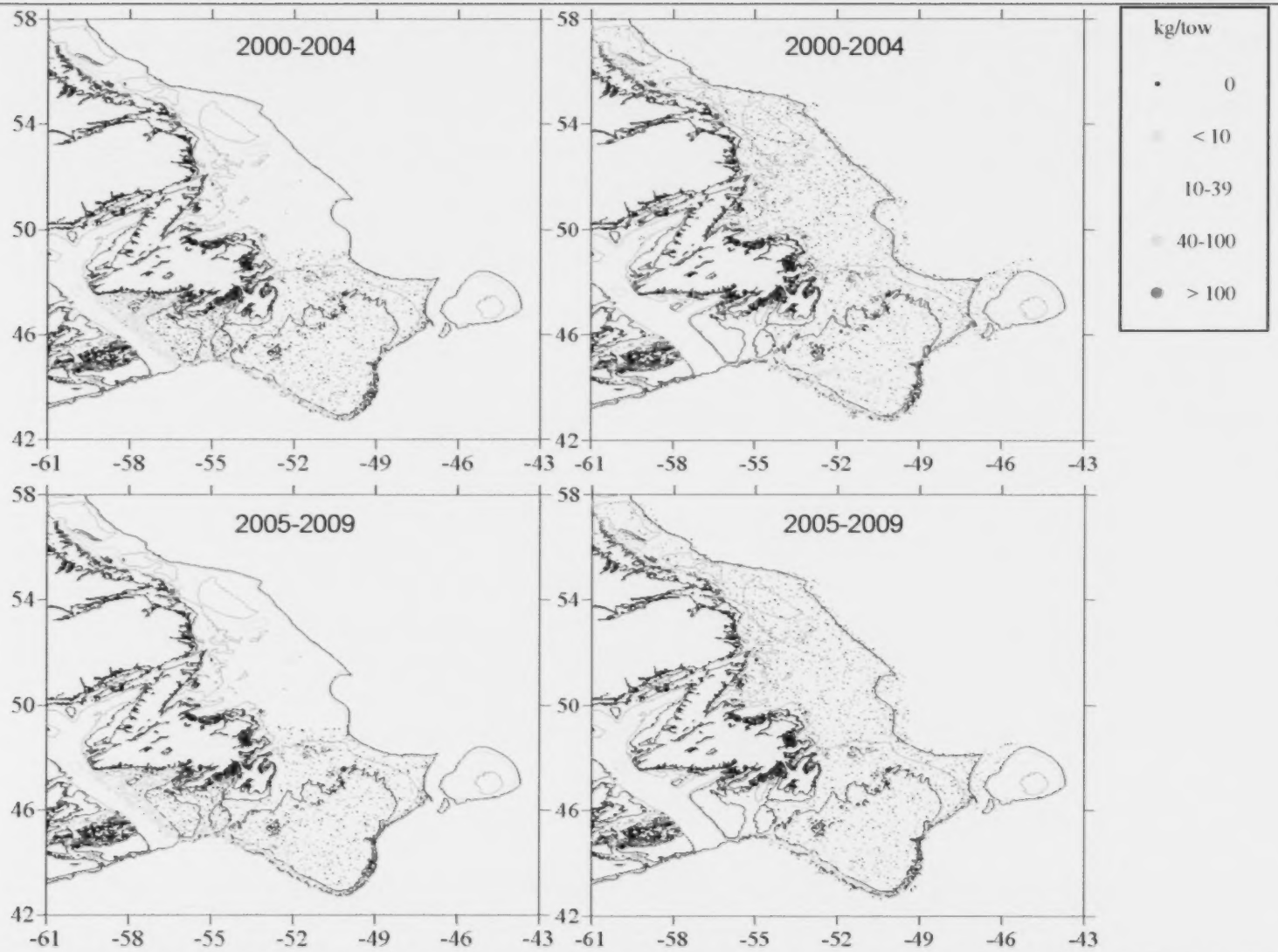

Figure 2 (cont.). Geographic distribution of spring (Left Panels) and fall (Right Panels) Canadian research survey catch rates (kg/tow) for White Hake in NAFO Div. 2GHJ3KLMNO and Subdiv. 3Ps. Note that Subdiv. 3Ps was not surveyed in the fall.

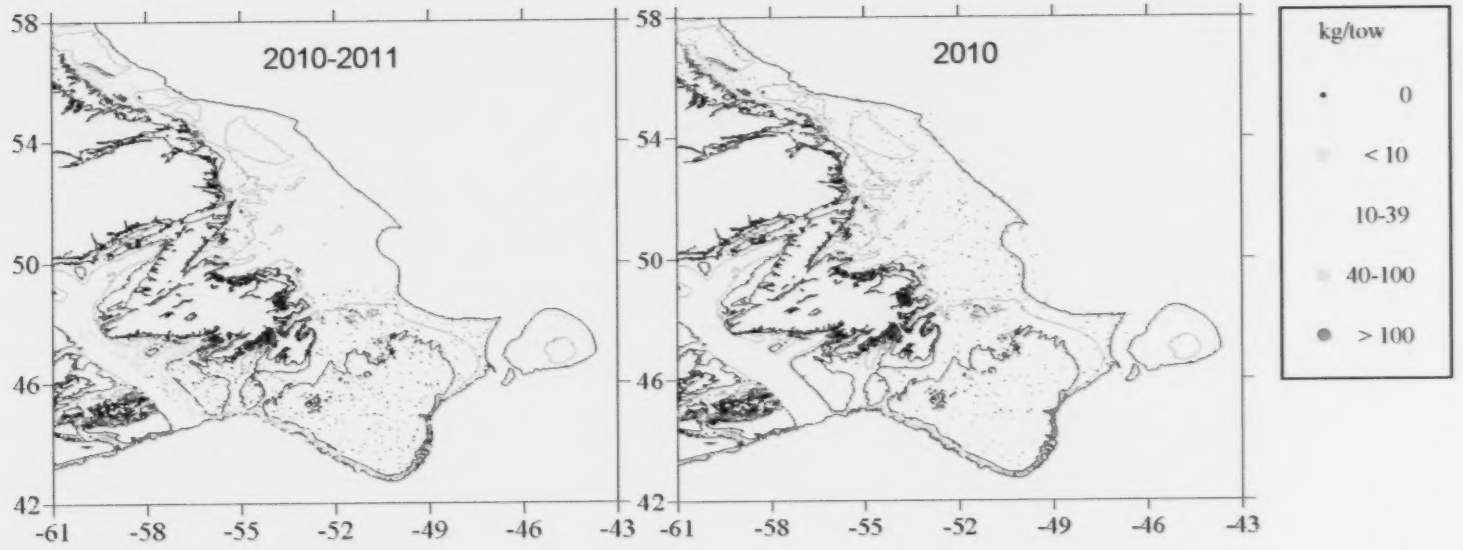

Figure 2 (cont.). Geographic distribution of spring (Left Panel) and fall (Right Panel) Canadian research survey catch rates (kg/tow) for White Hake in NAFO Div. 2GHJ3KLMNO and Subdiv. 3Ps. Note that Subdiv. 3Ps was not surveyed in the fall.

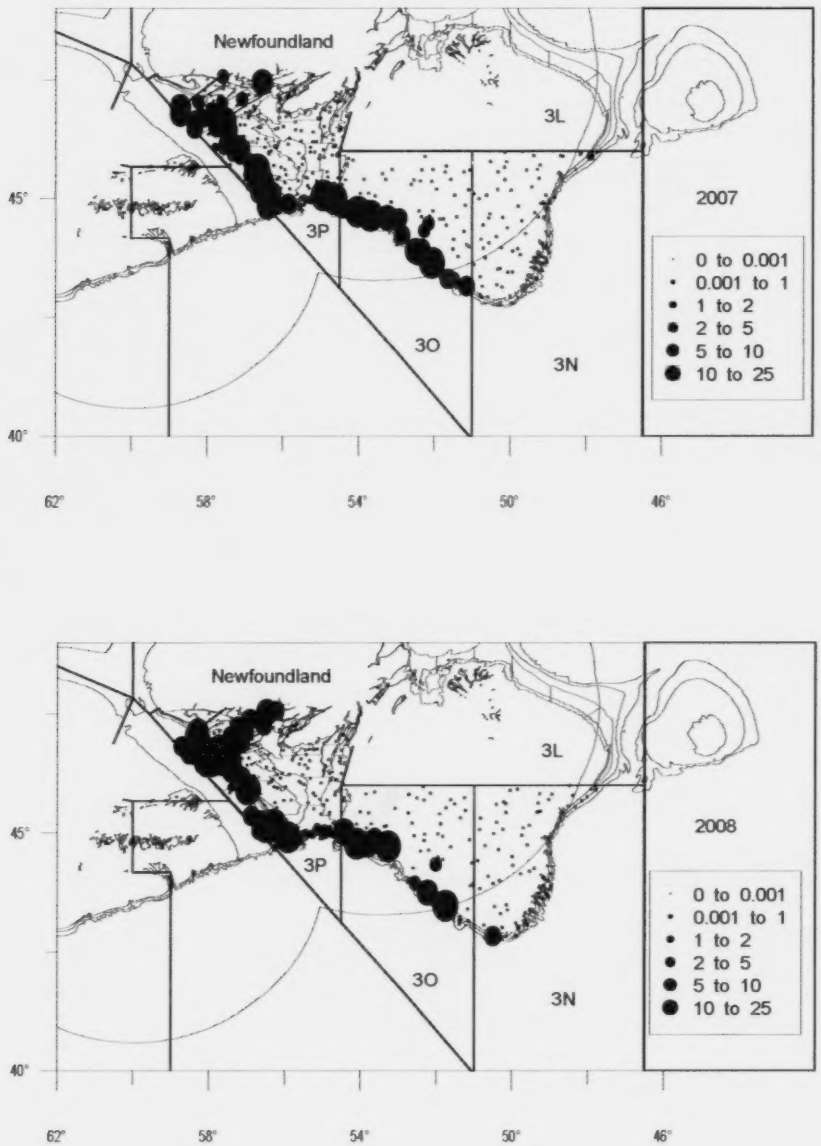

Figure 3. Distribution of White Hake numbers per tow in NAFO Div. 3NO and Subdiv. 3Ps; based on Canadian spring research surveys in 2007 (Upper Panel) and 2008 (Lower Panel).

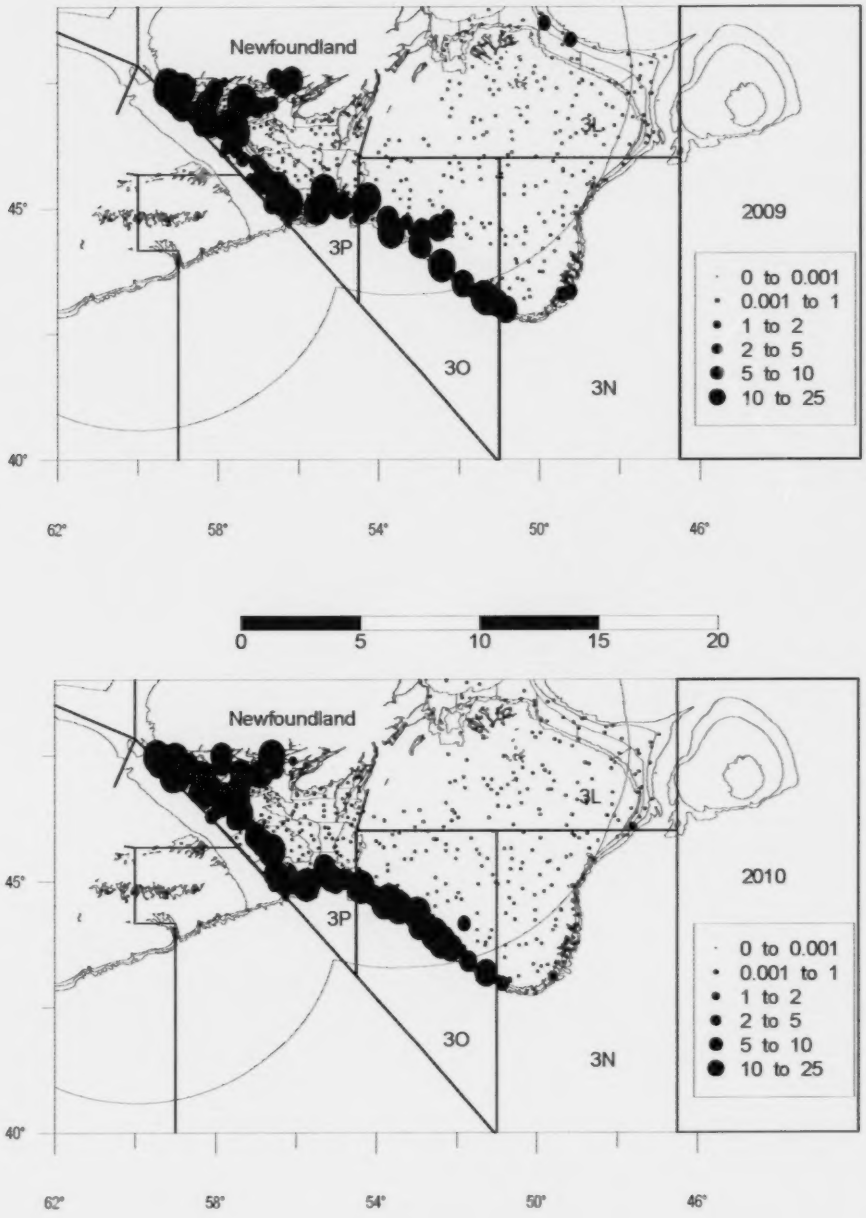

Figure 3 (cont.). Distribution of White Hake numbers per tow in NAFO Div. 3NO and Subdiv. 3Ps; based on Canadian spring research surveys in 2009 (Upper Panel) and 2010 (Lower Panel).

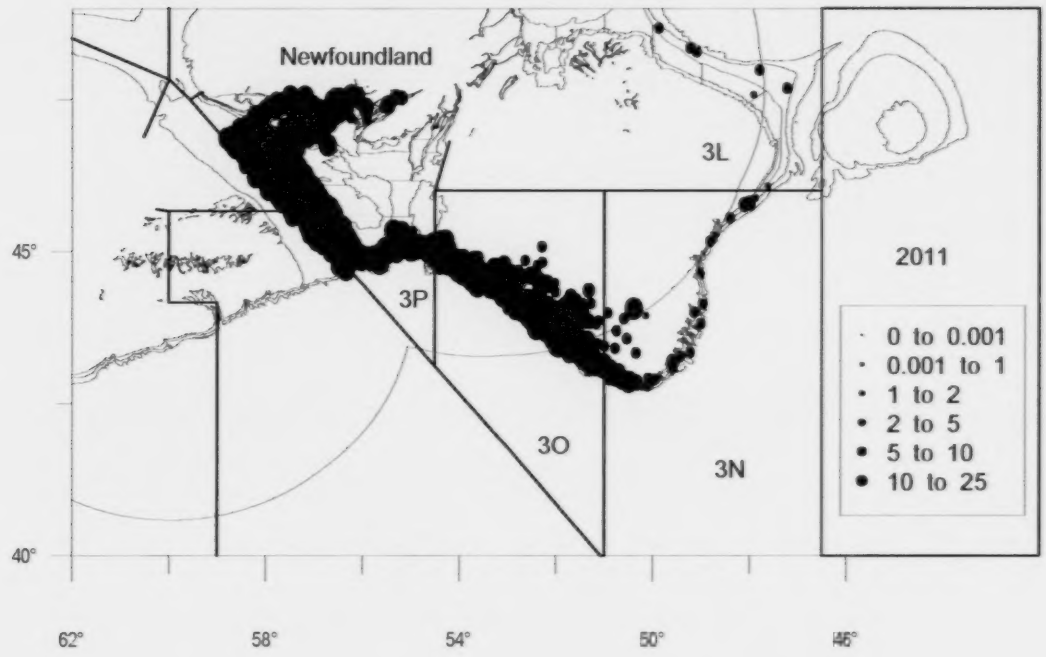

Figure 3 (cont.). Distribution of White Hake numbers per tow in NAFO Div. 3NO and Subdiv. 3Ps; based on Canadian spring research surveys in 2011.

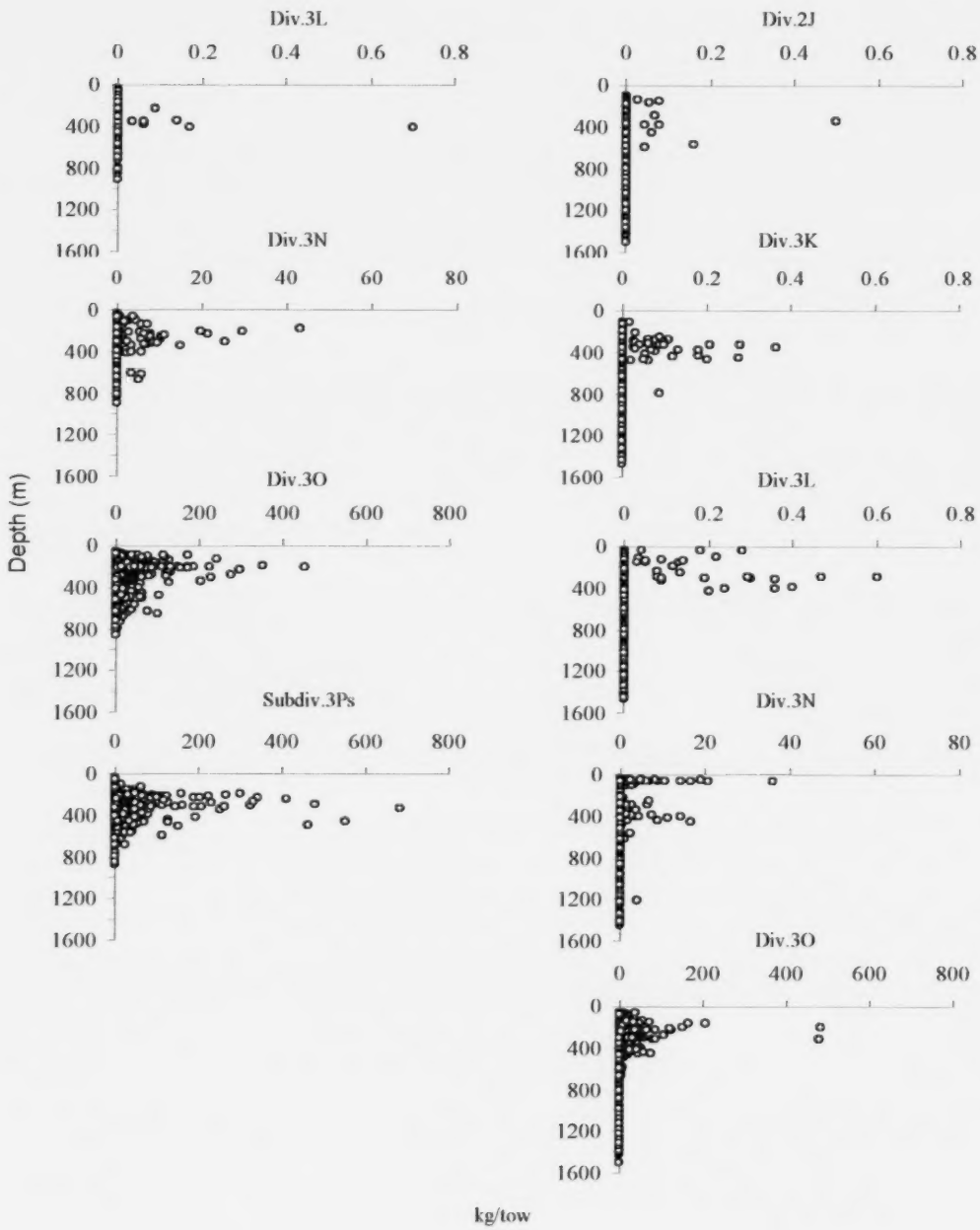

Figure 4. Distribution of White Hake catch rates (kg/tow) in relation to depth during spring (1971-2011; Left Column) and fall (1977-2010; Right Column) Canadian research surveys in Div. 2J3KLNO and Subdiv. 3Ps. Note that Subdiv. 3Ps was not surveyed in the fall.

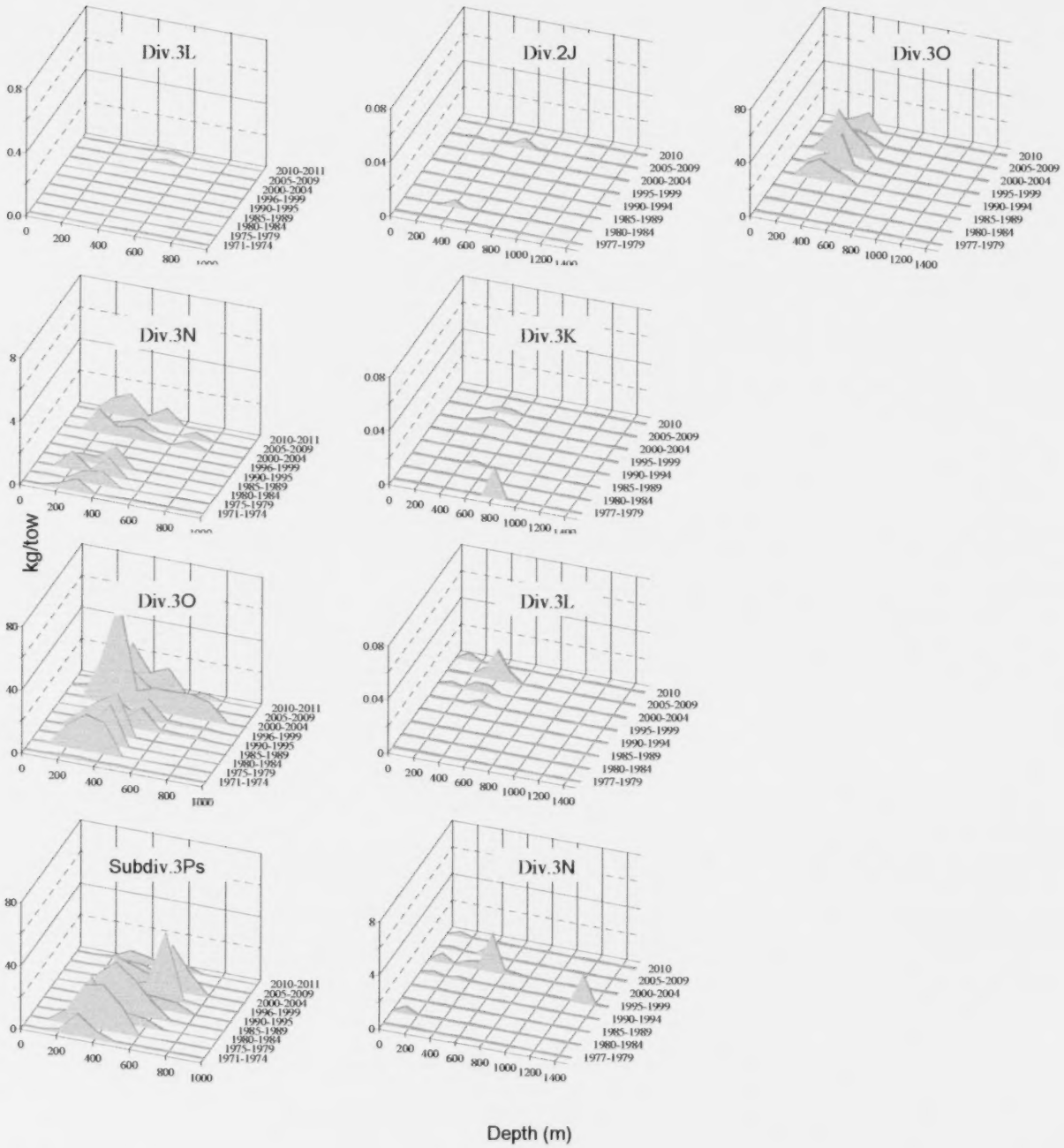

Figure 5. Distribution of White Hake mean catch rates in relation to depth during spring (1971-2011; Left Column) and fall (1977-2010; Right Columns) Canadian research surveys in Div. 2J3KLNO and Subdiv. 3Ps. Note that Subdiv. 3Ps was not surveyed in the fall.

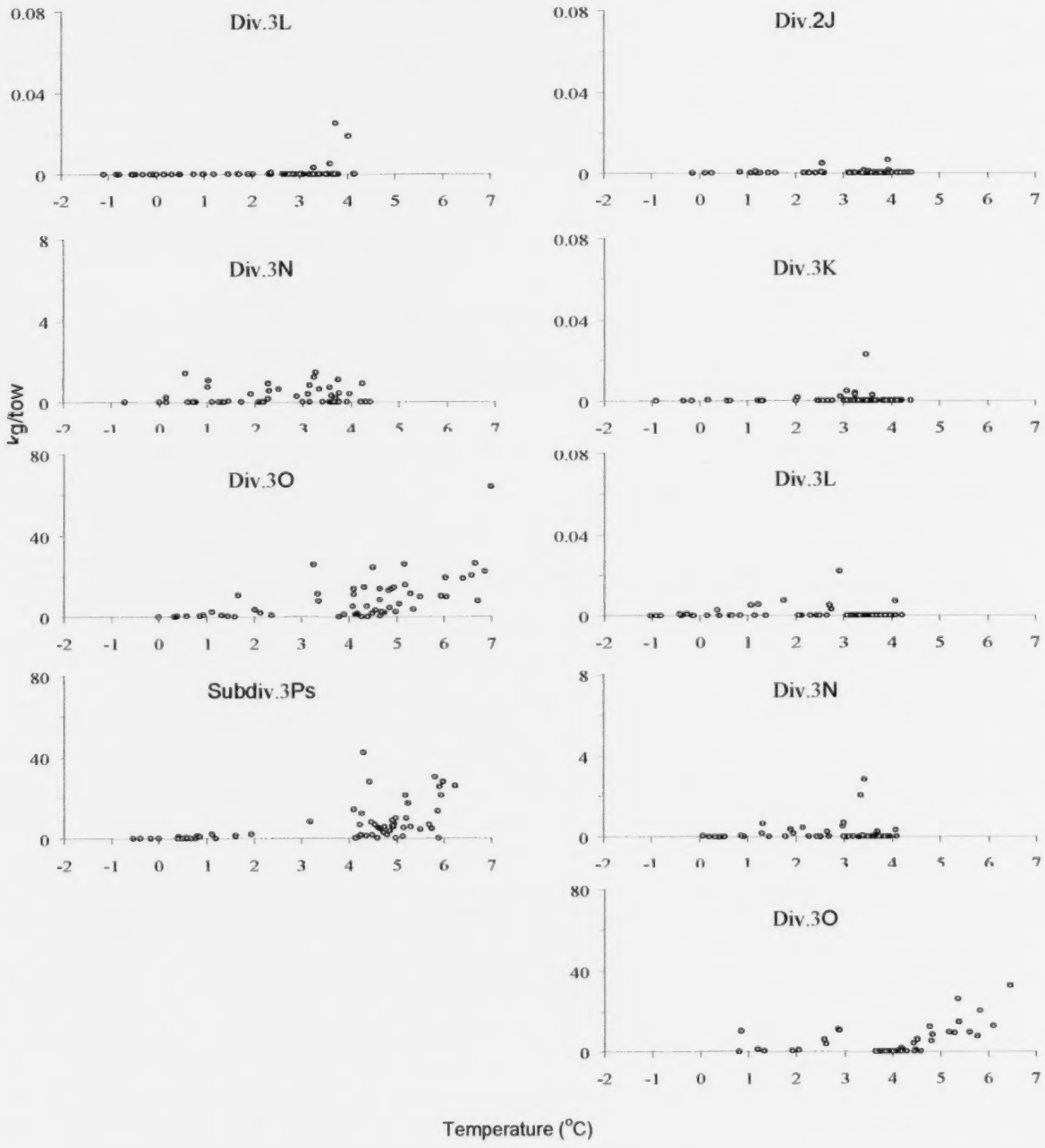

Figure 6. Distribution of White Hake mean catch rates in relation to water temperature at tow depth during spring (1971-2011; Left Panels) and fall (1977-2010; Right Panels) Canadian research surveys in Div. 2J3KLNO and Subdiv. 3Ps. Note that Subdiv. 3Ps was not surveyed in the fall.

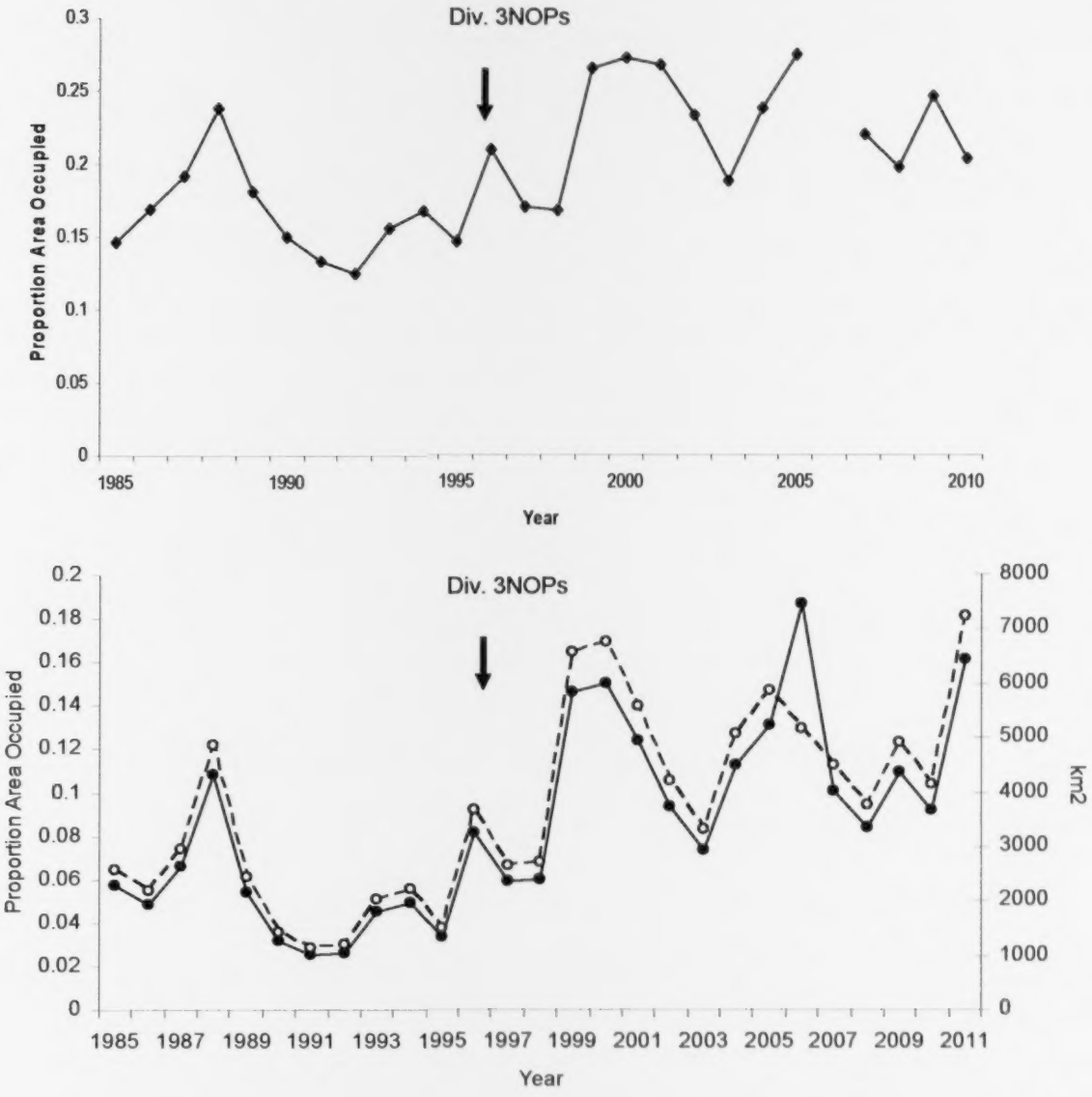

Figure 7. Area of occupancy for White Hake in Div. 3NO and Subdiv. 3Ps during spring, 1985-2011. Arrows denote a change in trawl gear from Engel to Campelen in 1996. Upper Panel depicts all strata; Lower Panel depicts index strata. Actual area of occupancy (km^2) is presented only for the index strata because of coverage of survey area (all strata) varied through the years.

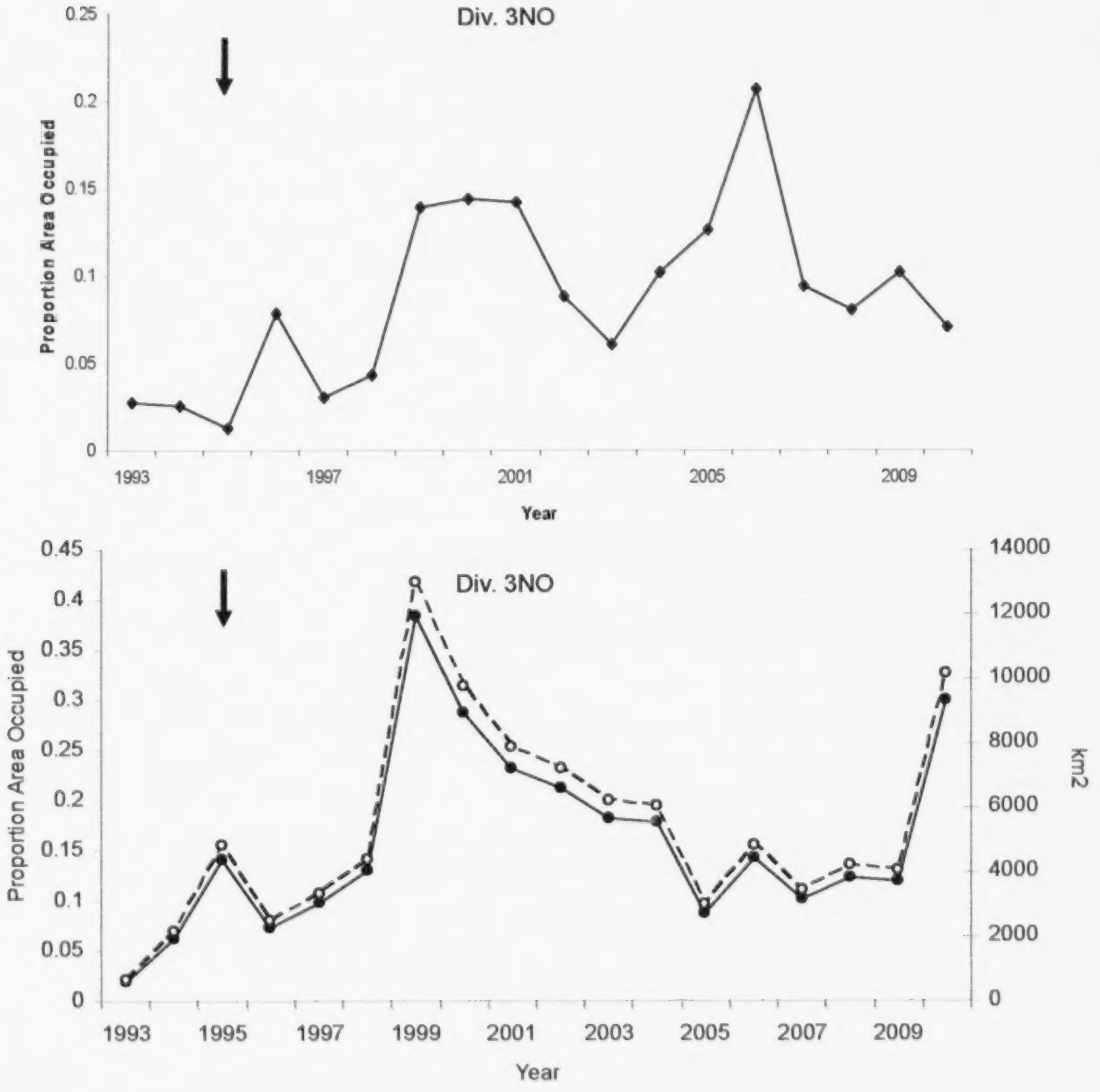

Figure 8. Area of occupancy for White Hake in Div. 3NO during fall, 1993-2011. Arrows denote a change in trawl gear from Engel to Campelen in 1995. Upper Panel depicts all strata; Lower Panel depicts index strata. Actual area of occupancy (km^2) is presented only for the index strata because of coverage of survey area (all strata) varied through the years.

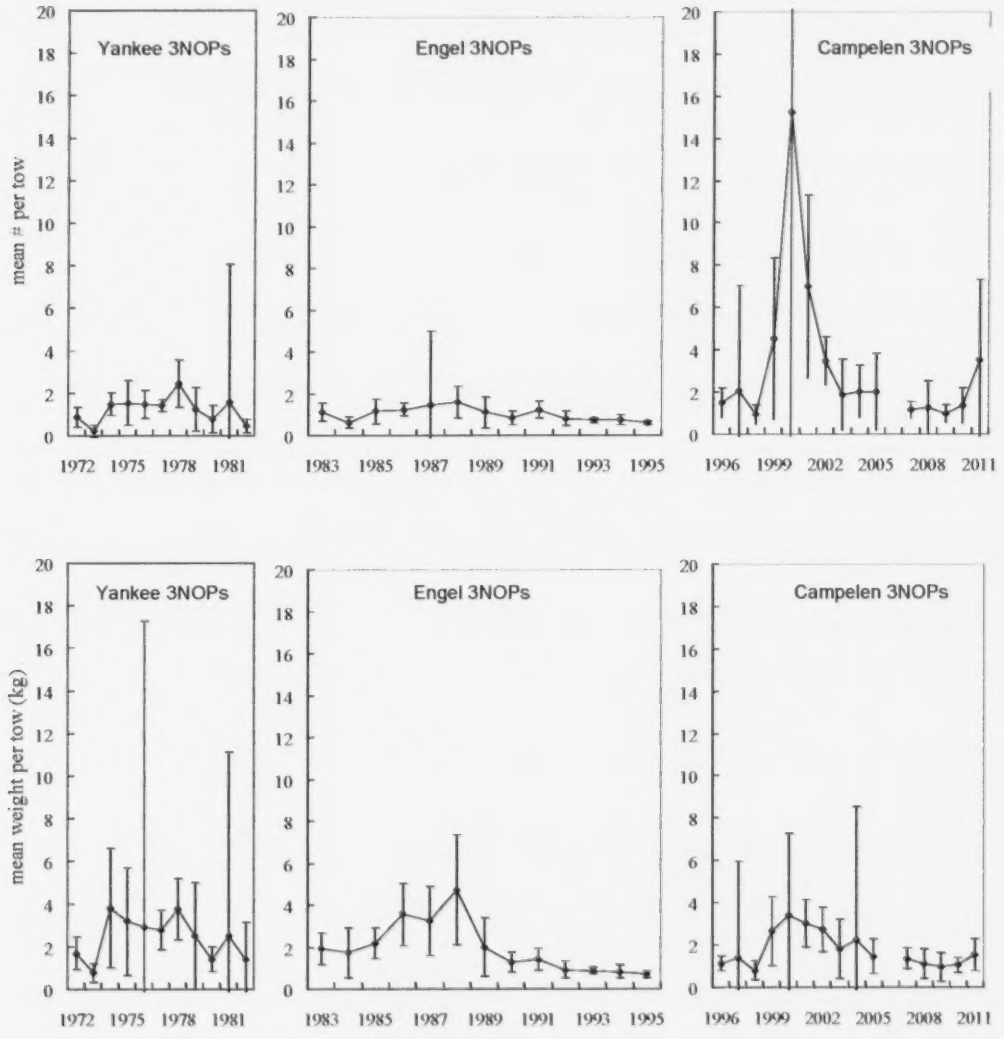

Figure 9. Mean numbers (Upper Panel) and mean weights (Lower Panel) per tow (+/- 95% CI) of White Hake from Canadian spring research surveys in NAFO Div. 3NO and Subdiv. 3Ps, 1972-2011. Yankee, Engel, and Campelen time series are not standardized, and thus are presented on separate panels. Note that deep strata in Div. 3NO and all of Subdiv. 3Ps were not surveyed in spring 2006.

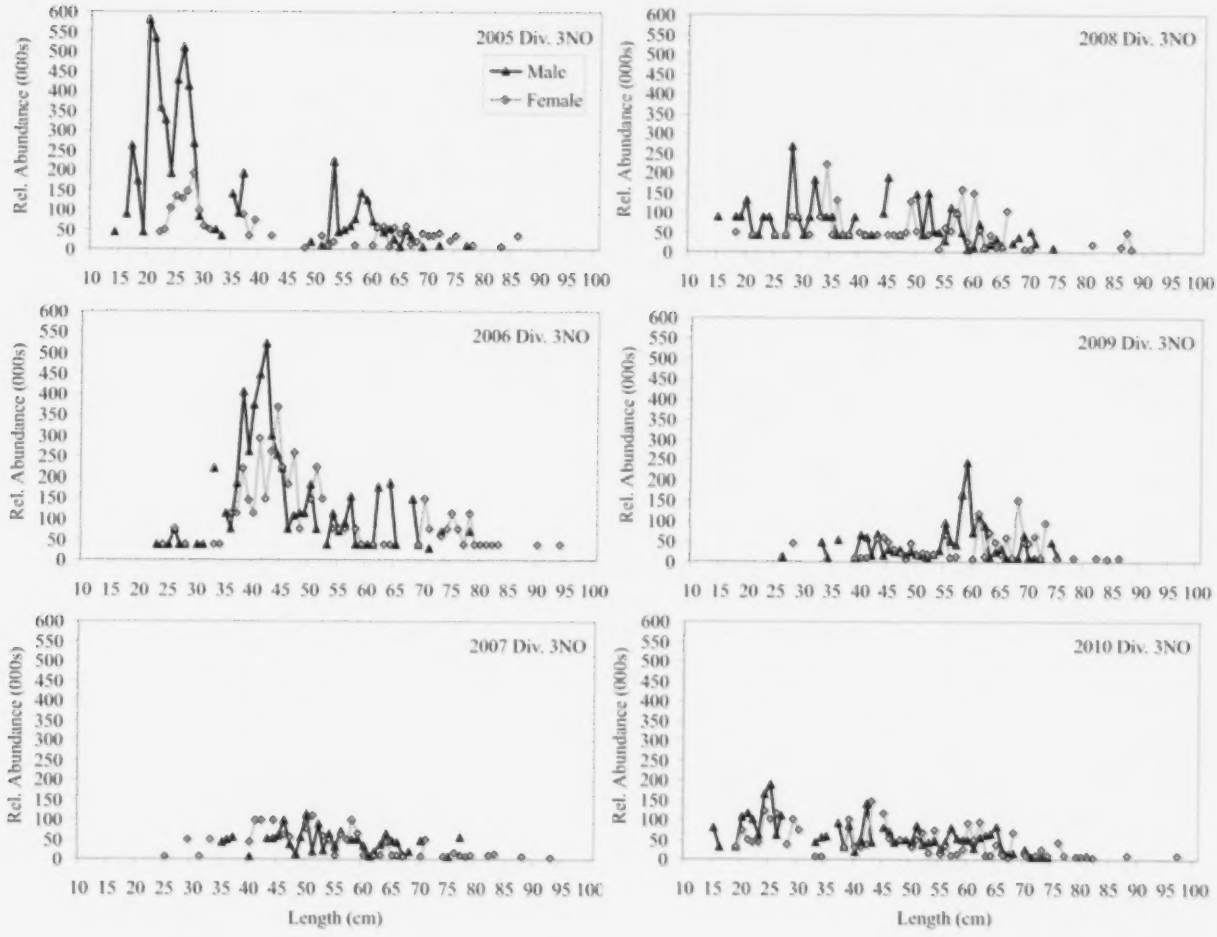

Figure 10. Relative abundance at length of male and female White Hake from Canadian spring research surveys in NAFO Div. 3NO, 2005-2010. Note that deep strata in Div. 3NO were not surveyed in spring 2006 due to Canadian research vessels' mechanical difficulties.

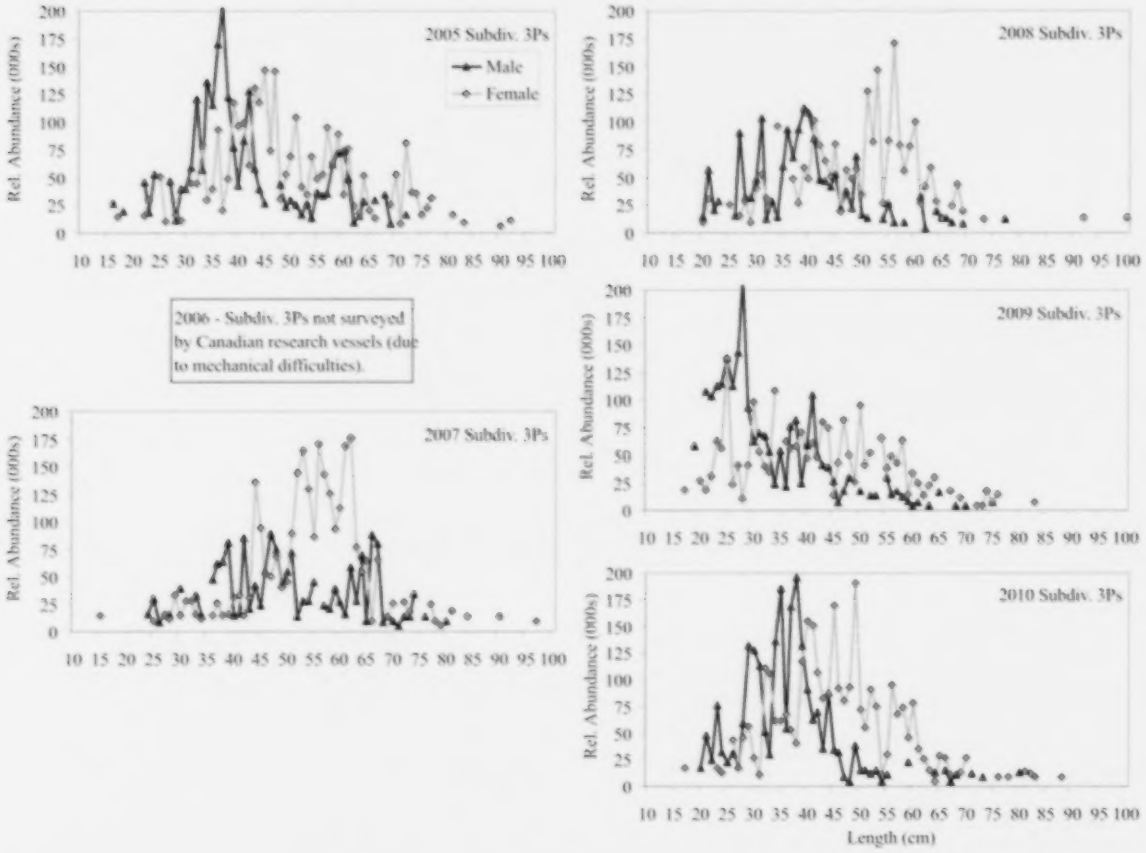

Figure 11. Relative abundance at length of male and female White Hake from Canadian spring research surveys in NAFO Subdiv. 3Ps, 2005-2010. Note that Subdiv. 3Ps was not surveyed in 2006 due to Canadian research vessels' mechanical difficulties.

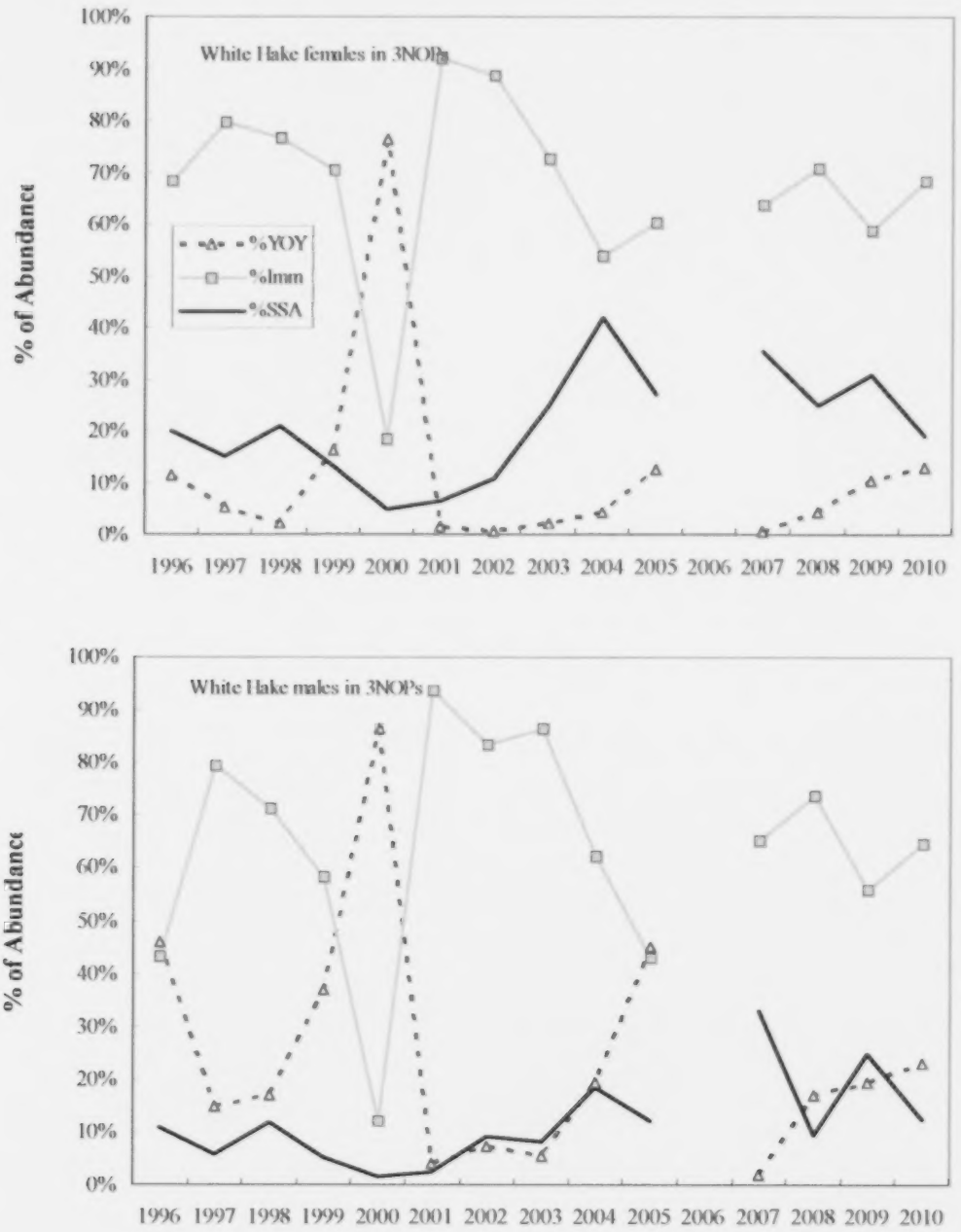

Figure 12. Staged trends in relative abundance of 1 year-old, immature, and mature female (Upper Panel), and male (Lower Panel) White Hake from Canadian Campelen spring surveys in NAFO Div. 3NO and Subdiv. 3Ps, 1996-2010. Note that deep strata in Div. 3NO and all of Subdiv. 3Ps were not surveyed in 2006; due to Canadian research vessels' mechanical difficulties.

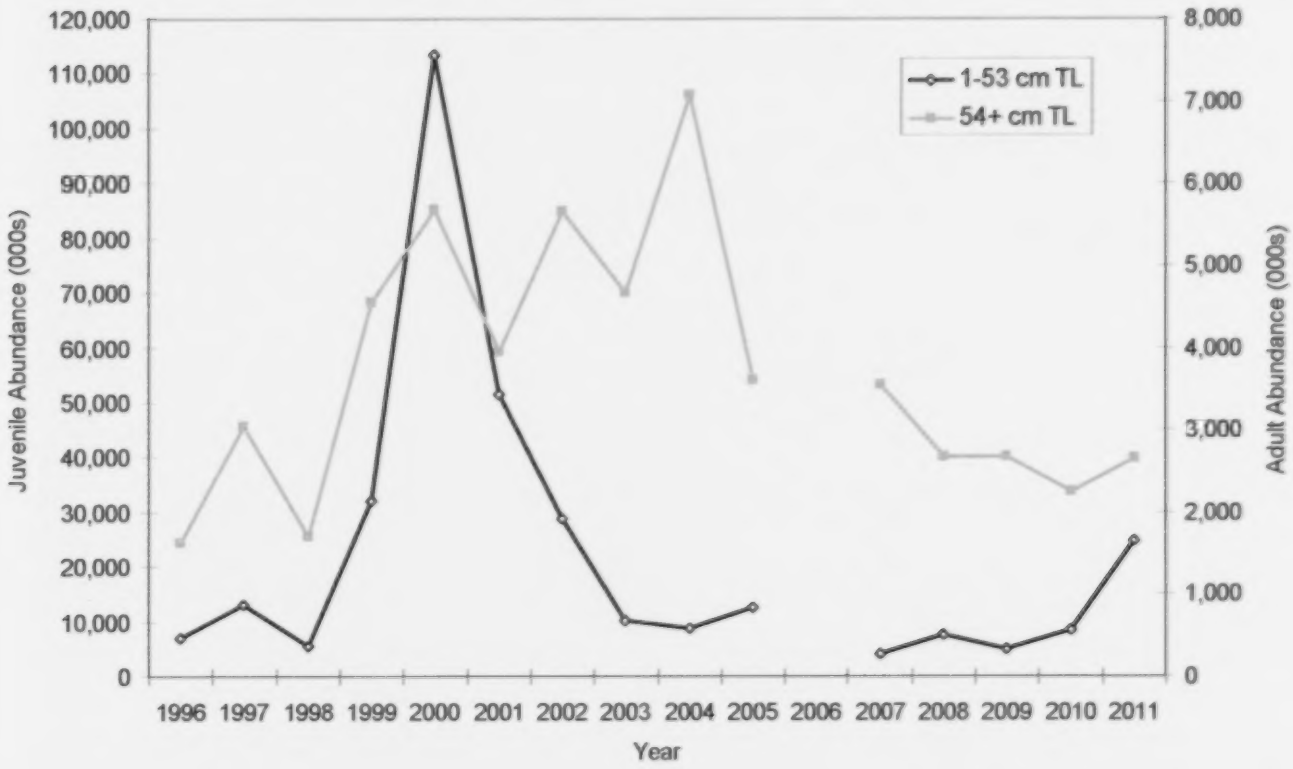

Figure 13. Relative abundance of juvenile (1-53 cm TL) and adult (54+ cm TL) White Hake (sexes combined) from Canadian Campelen spring surveys in NAFO Div. 3NO and Subdiv. 3Ps, 1996-2011. Note that deep strata in Div. 3NO and all of Subdiv. 3Ps were not surveyed in 2006; due to Canadian research vessels' mechanical difficulties.

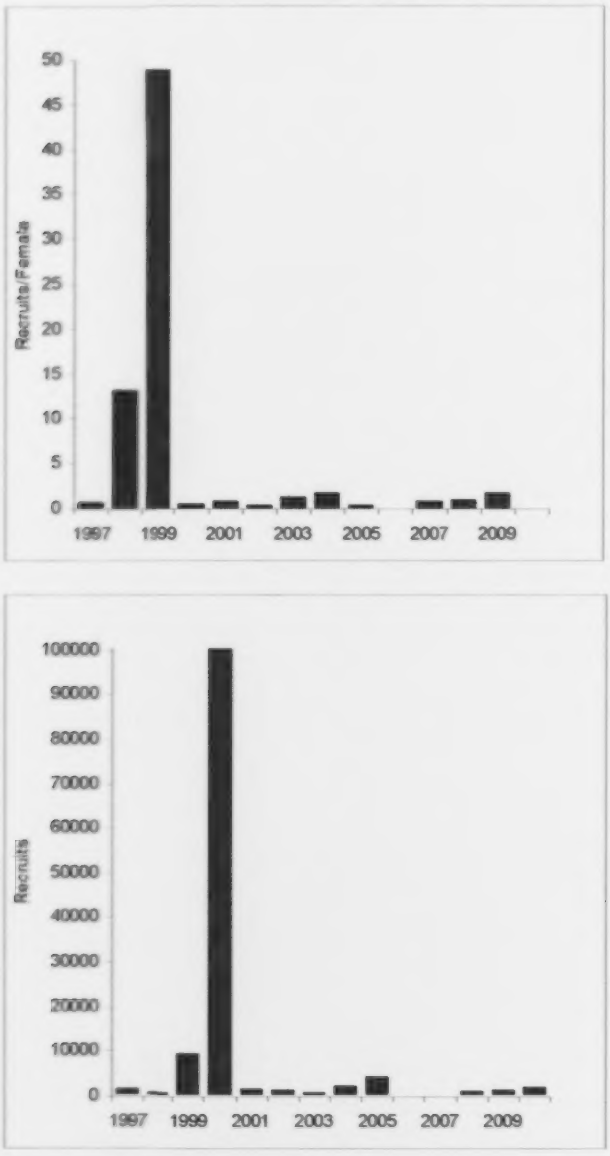

Figure 14. Recruits per spawner expressed as number of Age-1 males and females (1 year-olds produced per adult female in Year-1) from Canadian Campelen spring surveys in NAFO Div. 3NO and Subdiv. 3Ps, 1997-2009 (Upper Panel). White Hake recruits from Canadian Campelen spring surveys in Div. 3NO and Subdiv. 3Ps during 1997-2010 (Lower Panel). For the 2005 point, one-year-olds in 2006 were only from the shallow (<103 m) portion of Div. 3NO; rather than from the entire stock area, because of incomplete Canadian survey coverage in that year.

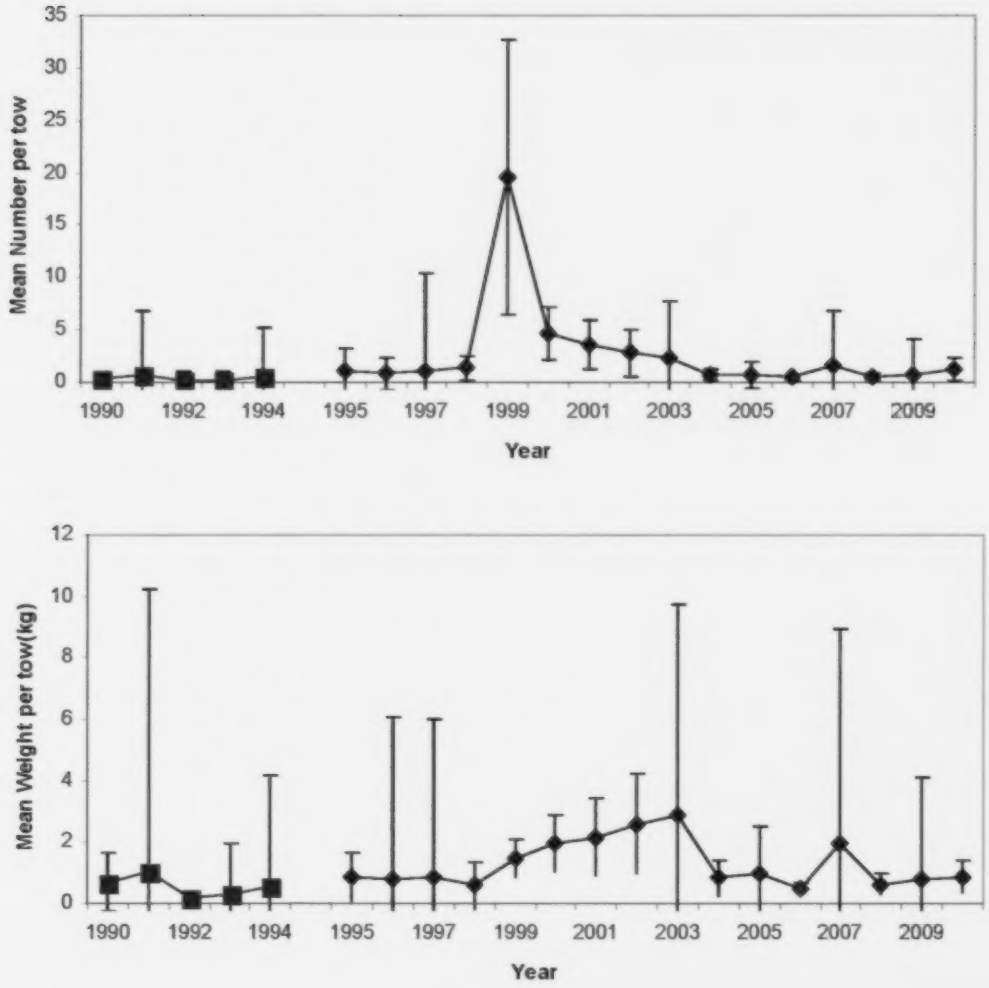

Figure 15. Mean numbers (Upper Panel) and mean weights (Lower Panel) per tow of White Hake from Canadian fall research surveys in NAFO Div. 3NO. Engel (1990-1994) and Campelen (1995-2010) time series are not standardized. Note that deep strata in Div. 3NO were not surveyed in fall of 2003, 2004, 2006, and strata deeper than 730 m in the survey area were not surveyed in fall 2008; due to Canadian research vessels' mechanical difficulties.

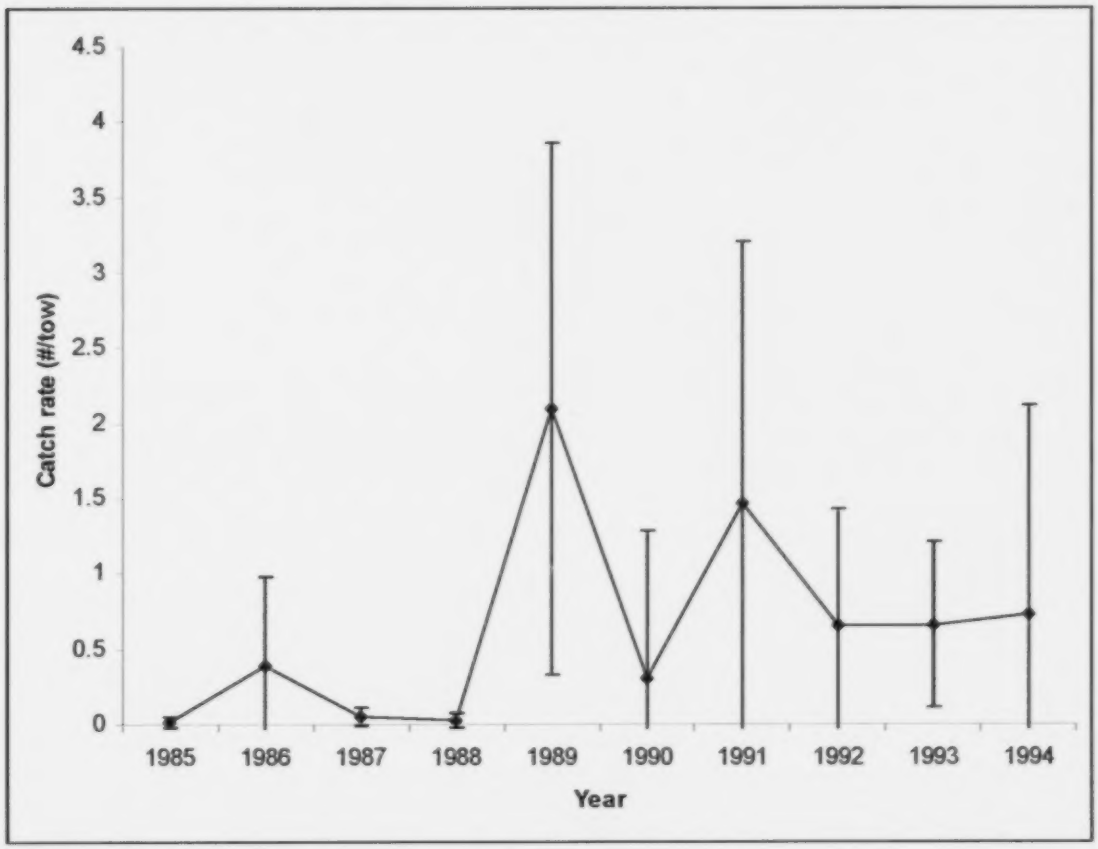

Figure 16. Juvenile groundfish bottom trawl research survey index of relative abundance (mean number/tow) for White Hake in Div. 3LNO (+/- 95% CI), 1985-1994.

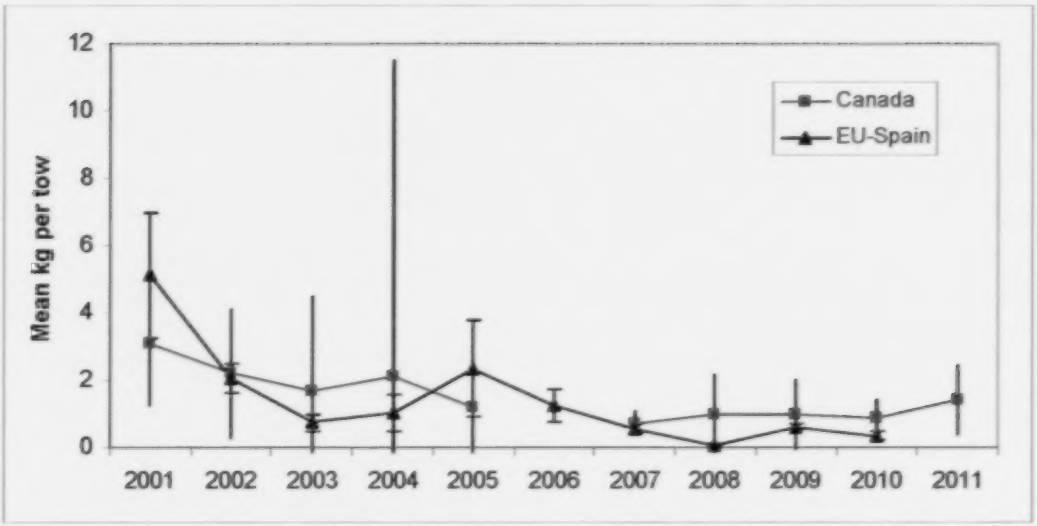

Figure 17. White Hake biomass indices in NAFO Div. 3NO: Spanish spring surveys in the NRA of Div. 3NO (González-Troncoso et al. 2011) compared to Canadian spring surveys in all of Div. 3NO, 2001-2011. Note that deep strata in Div. 3NO were not surveyed by Canada in spring 2006; due to research vessels' mechanical difficulties.

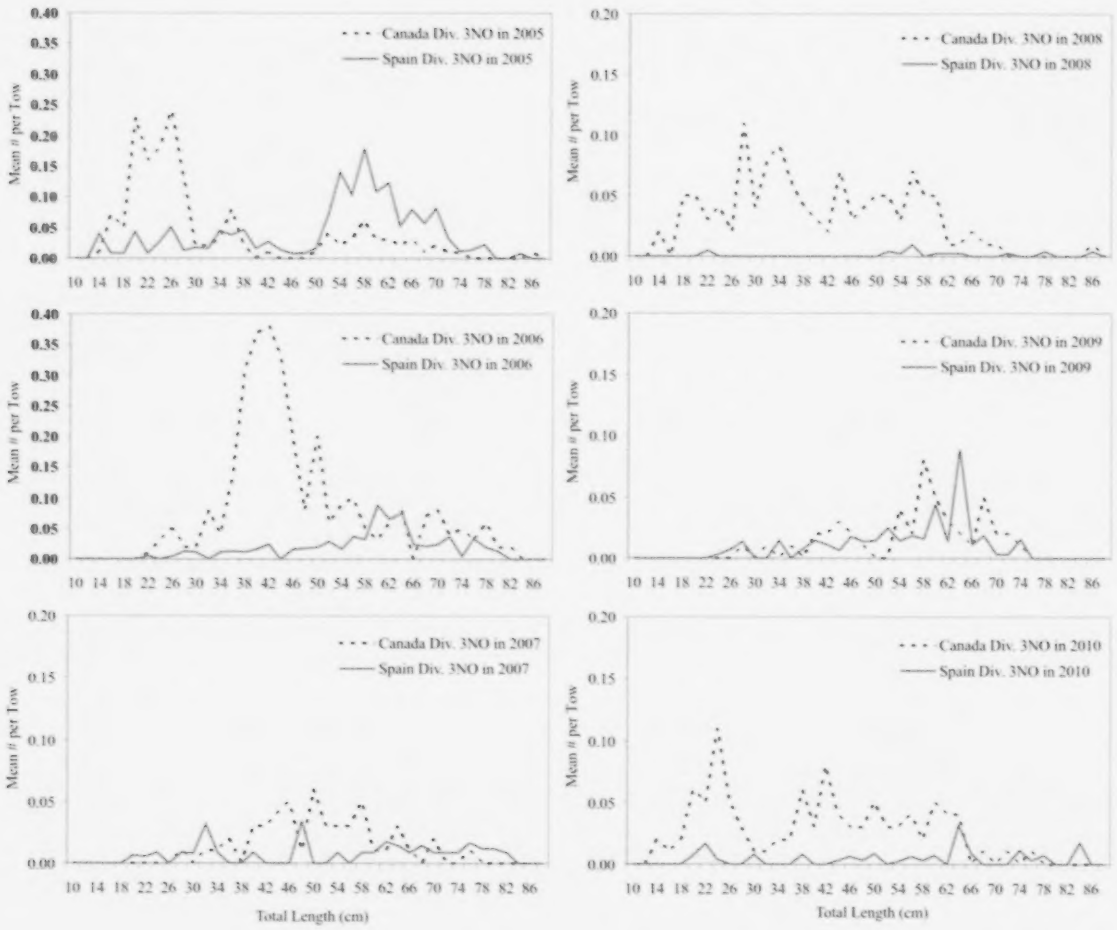
Canada Div. 3NO in 2005
Spain Div. 3NO in 2005
Canada Div. 3NO in 2008
Spain Div. 3NO in 2008
Canada Div. 3NO in 2006
Spain Div. 3NO in 2006
Canada Div. 3NO in 2009
Spain Div. 3NO in 2009
Canada Div. 3NO in 2007
Spain Div. 3NO in 2007
Canada Div. 3NO in 2010
Spain Div. 3NO in 2010
Mean # per Tow
Total Length (cm)

Figure 18. Abundance at length from Canadian Campelen and Spanish Campelen spring research surveys in NAFO Div. 3NO (Spanish surveys limited to NRA), 2005-2010. Number per tow was calculated using mean catches. Note that Y-axes for 2007-2010 are half the value of those for 2005-2006.

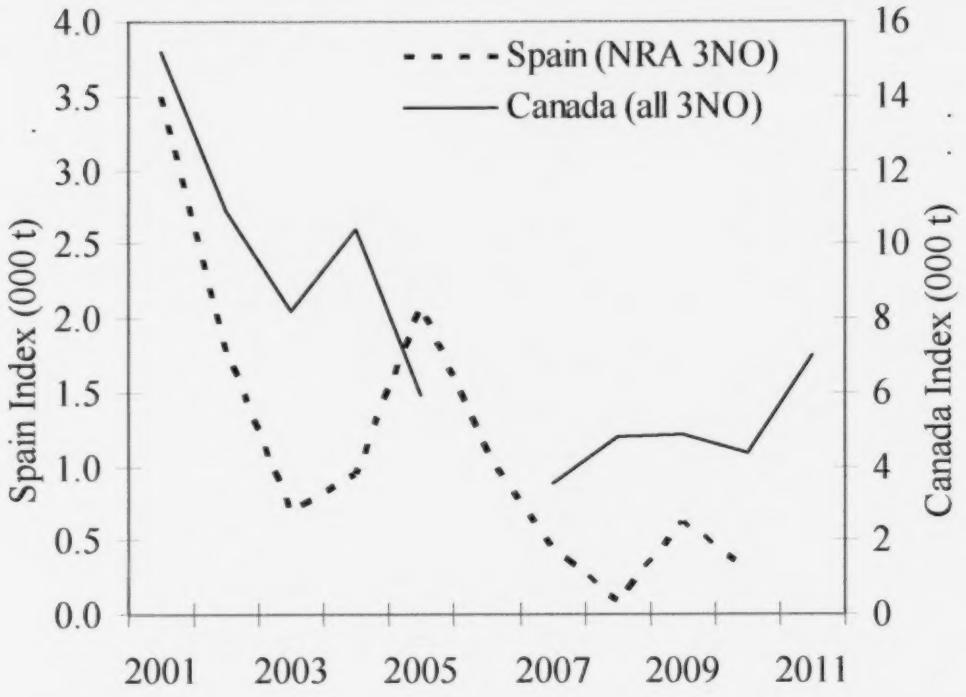

Figure 19. White Hake biomass indices in NAFO Div. 3NO: Spanish spring surveys in the NRA of Div. 3NO (González-Troncoso et al. 2011) compared to Canadian spring surveys in all of Div. 3NO, 2001-2011. Note that deep strata in Div. 3NO were not surveyed by Canada in spring 2006, due to research vessels' mechanical difficulties.

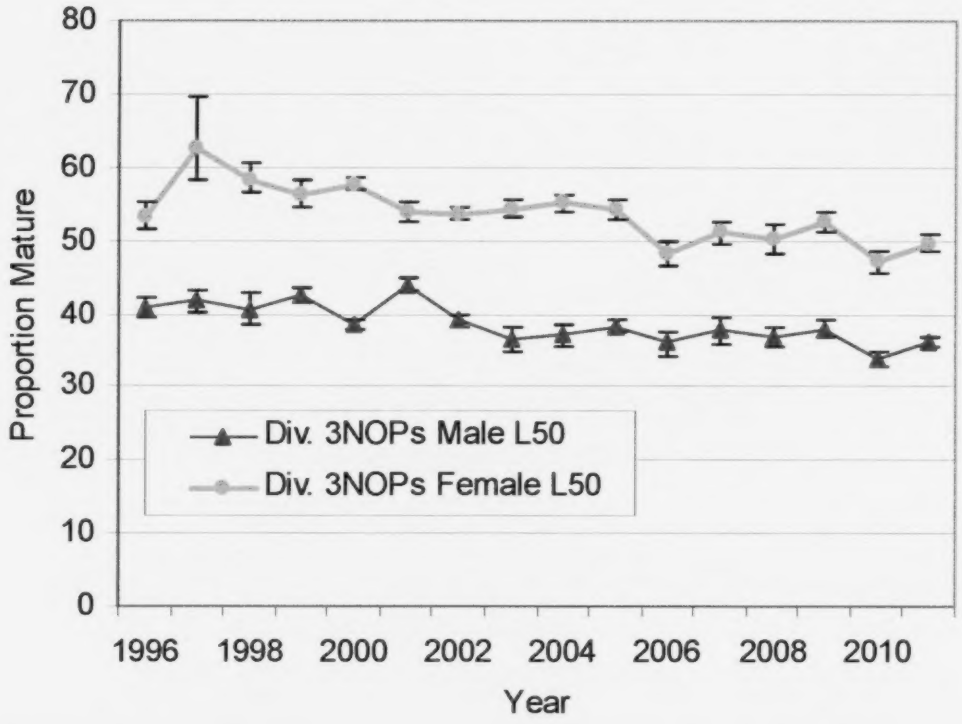

Figure 20. White Hake in Div. 3NOPs combined: Length at 50% maturity for each sex from Canadian Campelen spring surveys in 1996-2011.

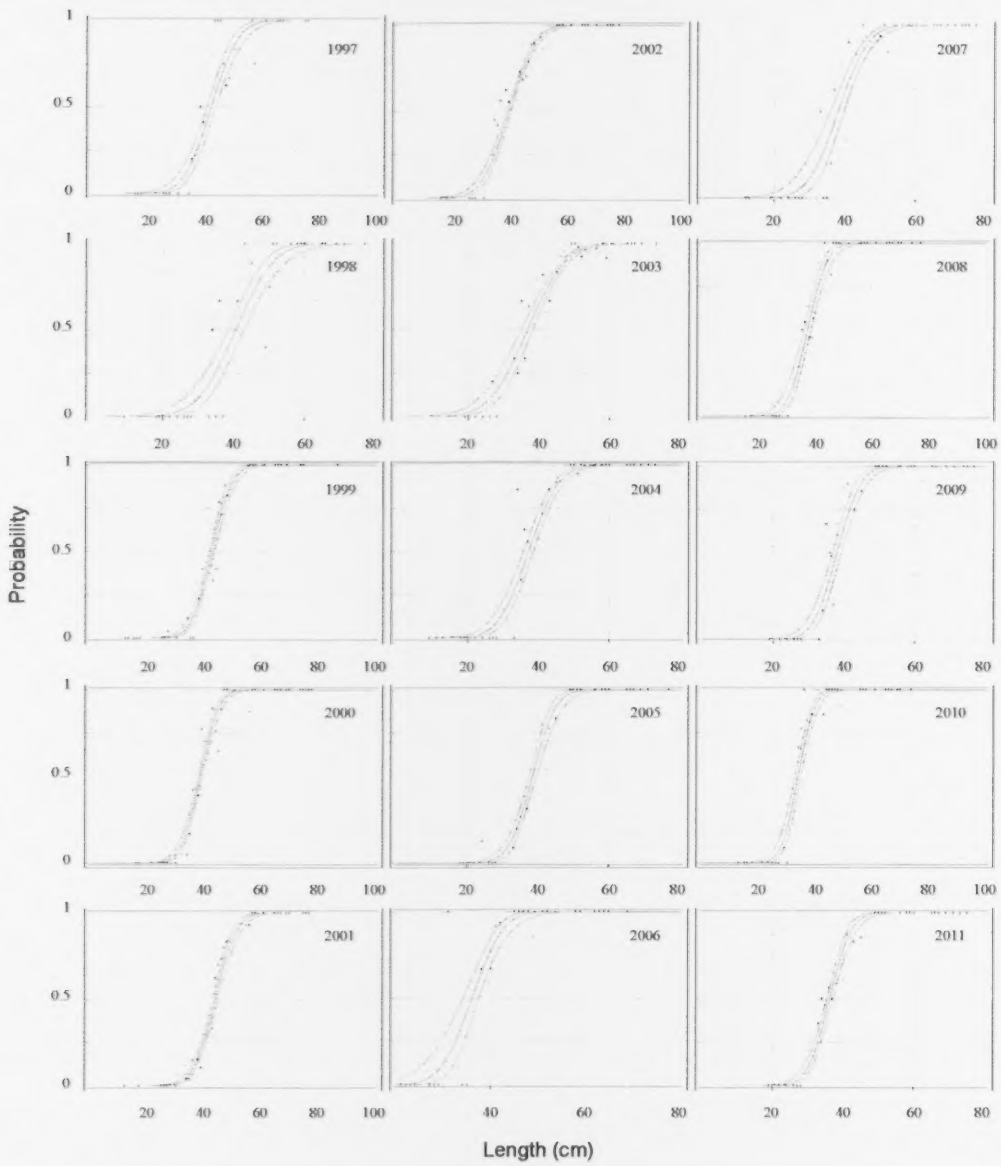

Figure 21a. White Hake in Div. 3NO and Subdiv. 3Ps: Annual maturity ogives for males from Canadian Campelen spring surveys in 1997-2011.

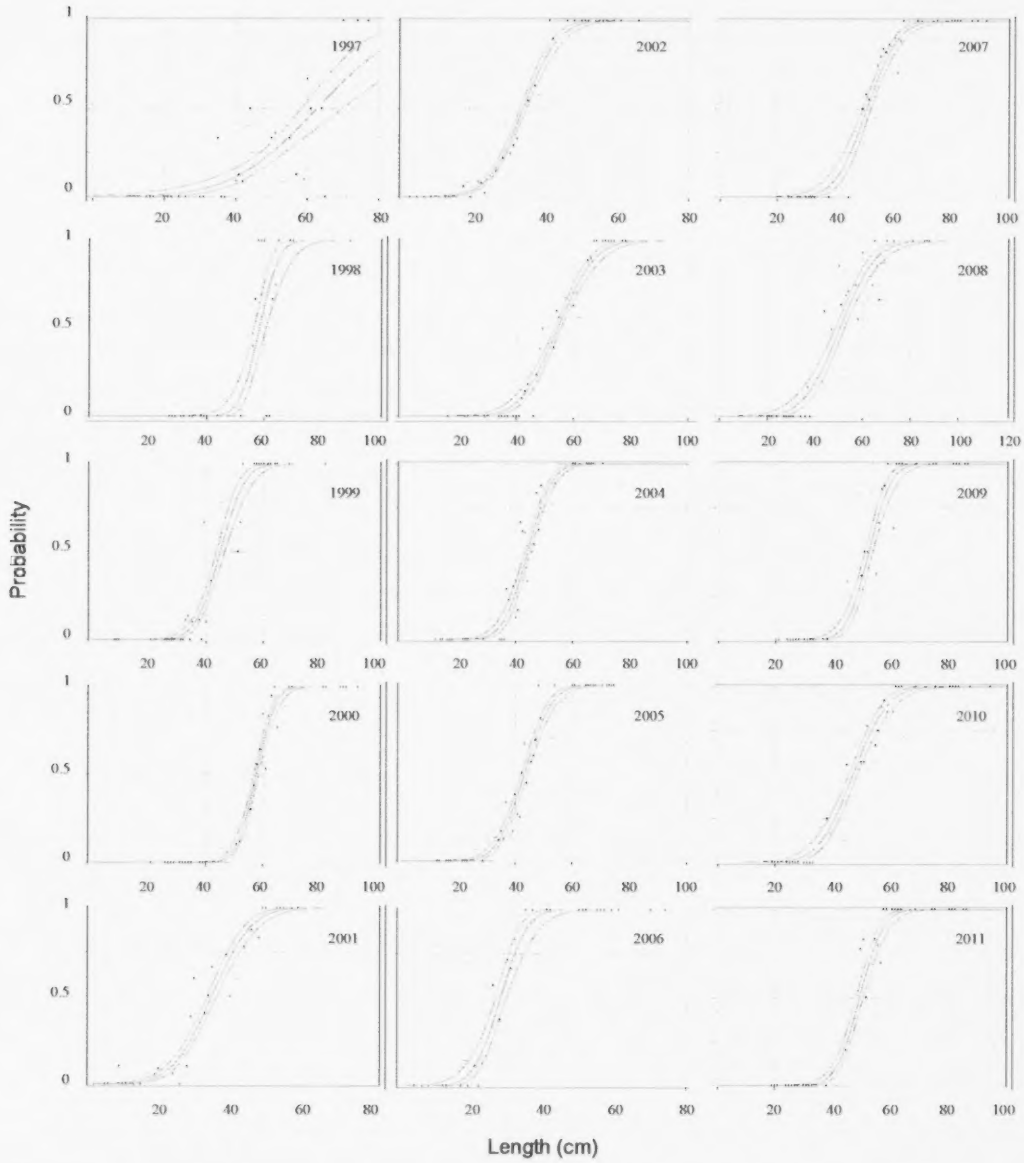

Figure 21b. White Hake in Div. 3NO and Subdiv. 3Ps: Annual maturity ogives for females from Canadian Campelen spring surveys in 1997-2011.

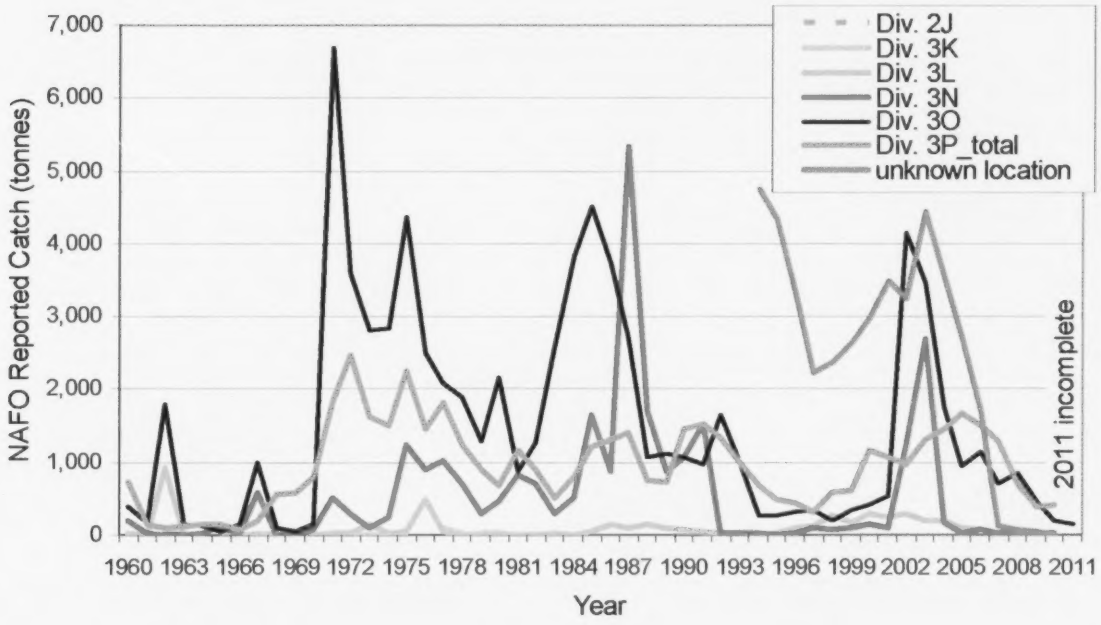

Figure 22. Reported catches (in tonnes) of White Hake by Canada and other countries in NAFO Subarea 2, Div. 3KLNOP, and unknown locations in 1960-2011. Data are from NAFO's STATLANT-21A database, and are incomplete for 2011.

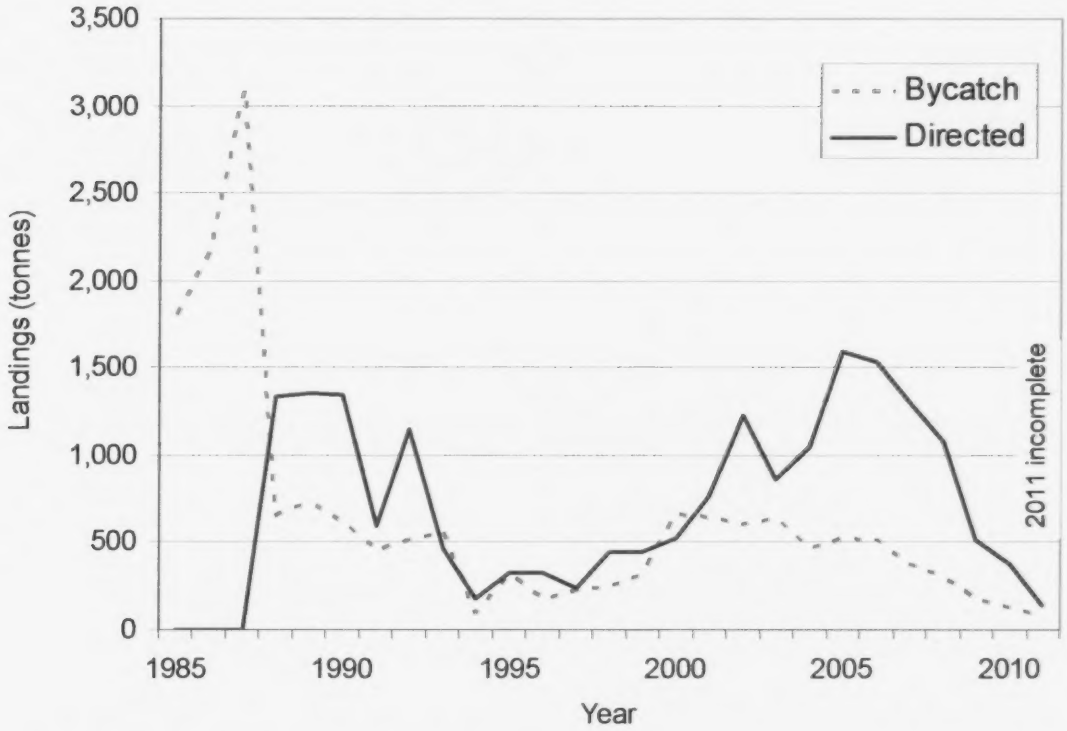

Figure 23. Directed and non-directed reported White Hake landings in Canada's EEZ of NAFO Div. 2J3KLNOP in 1985-2011. Data do not include discards at sea, and are incomplete for 2011.

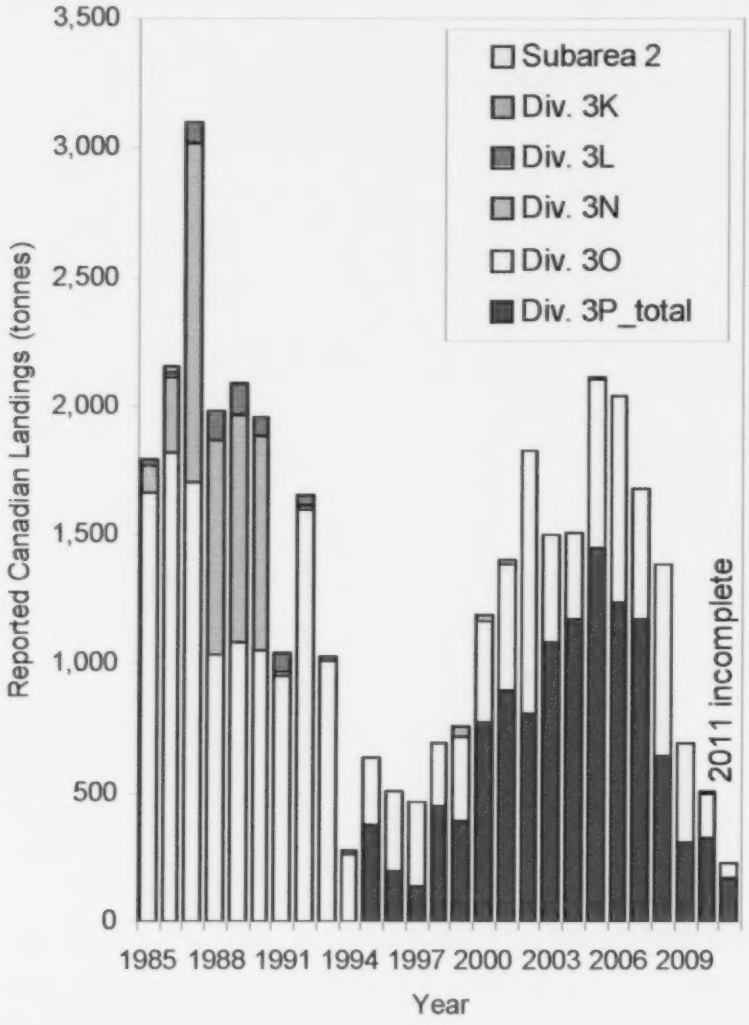

Figure 24. Reported White Hake landings in Canada's EEZ of NAFO Div. 2J3KLNOP in 1985-2011. Data do not include discards at sea, and are incomplete for 2011.

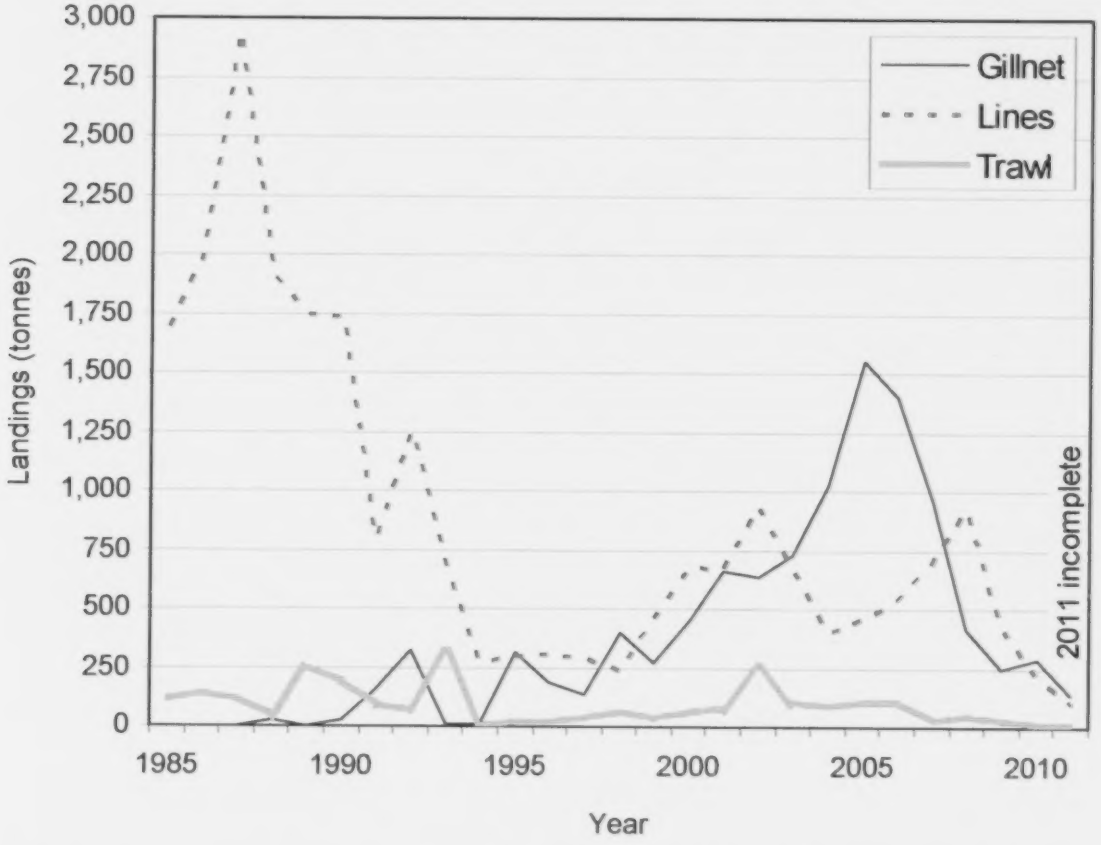

Figure 25. Reported White Hake landings by gear type in Canada's EEZ of NAFO Div. 2J3KLNOP in 1985-2011. Data do not include discards at sea, and are incomplete for 2011.

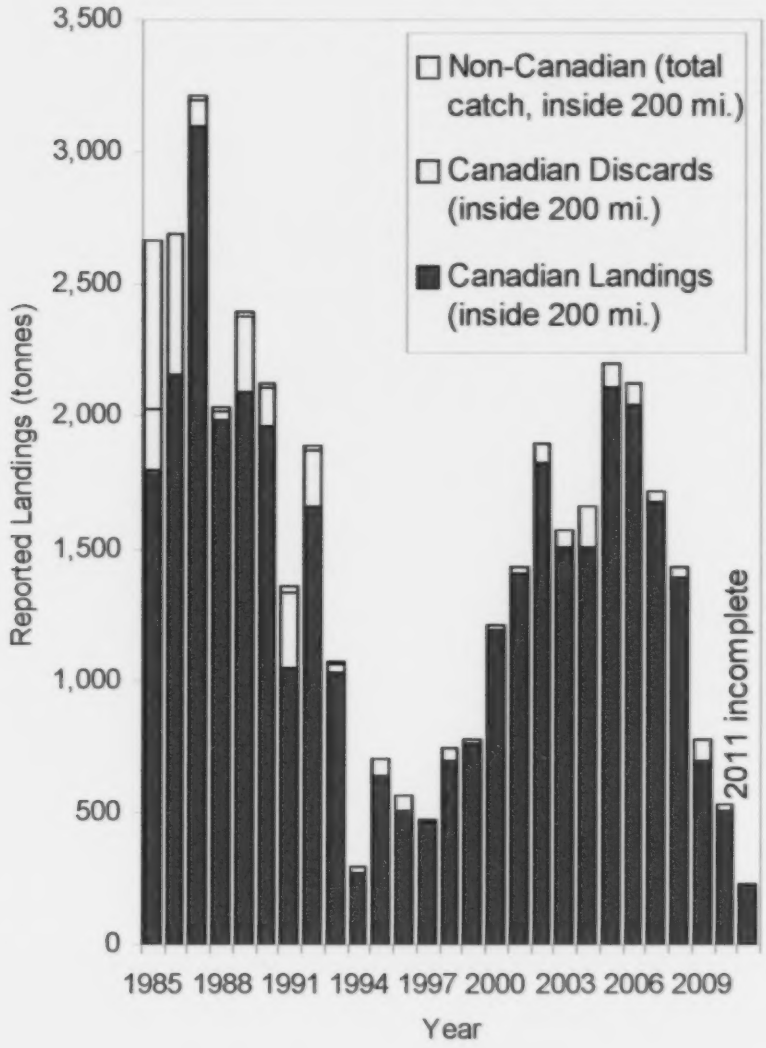

Figure 26. White Hake at-sea discard estimates from various commercial fisheries in Canada's EEZ of NAFO Div. 2J3KLNOP in 1985-2011. Discard and non-Canadian catch estimates are from Canadian Fisheries Observers, landings data are from the DFO ZIF database, and all are incomplete for 2011.

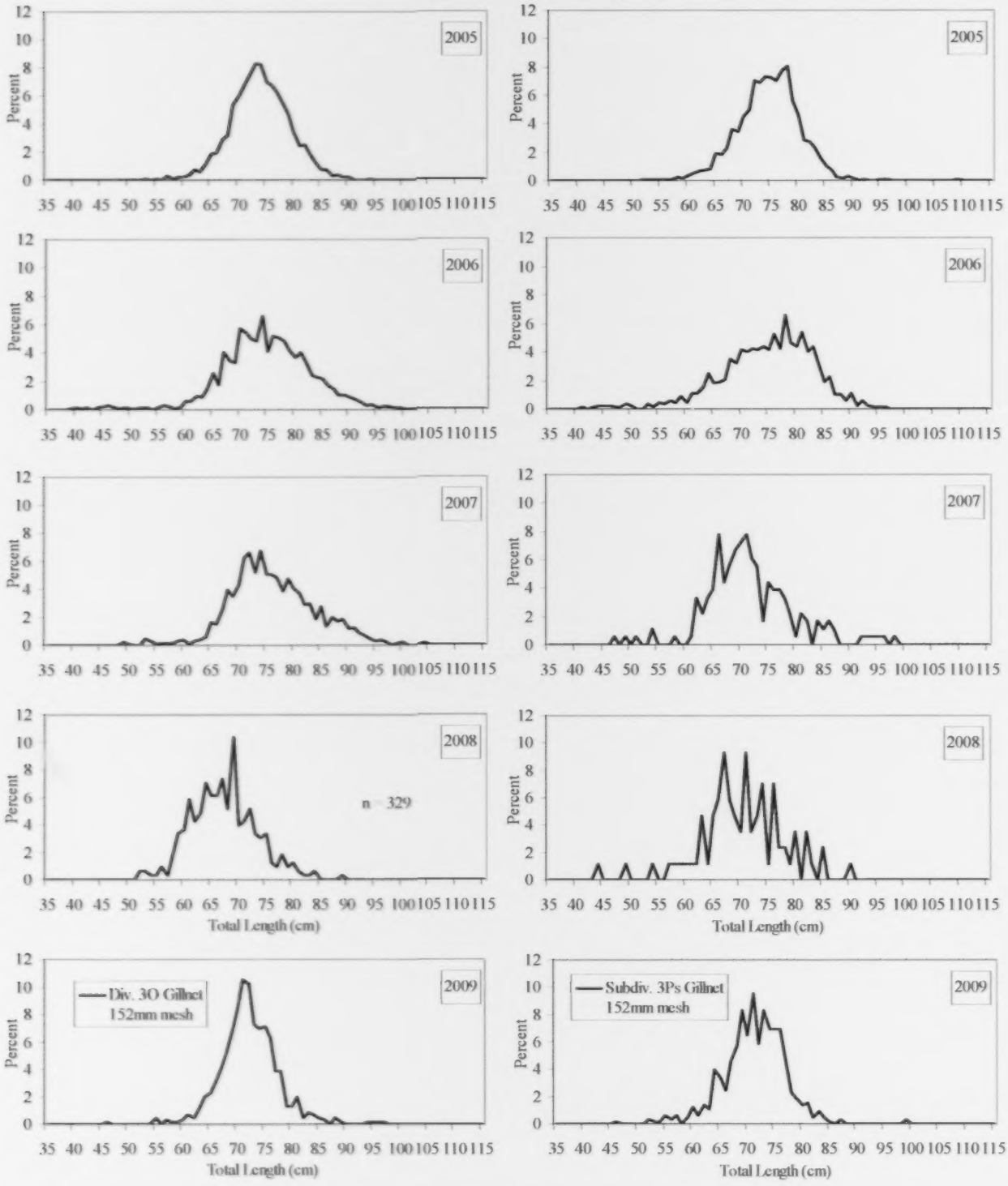

Figure 27a. Size of White Hake caught in NAFO Div. 3O and Subdiv. 3Ps by Canadian commercial gillnets, 2005-2009. Data are from Canadian Fisheries Observers. No Canadian gillnet length frequencies were available for 2010.

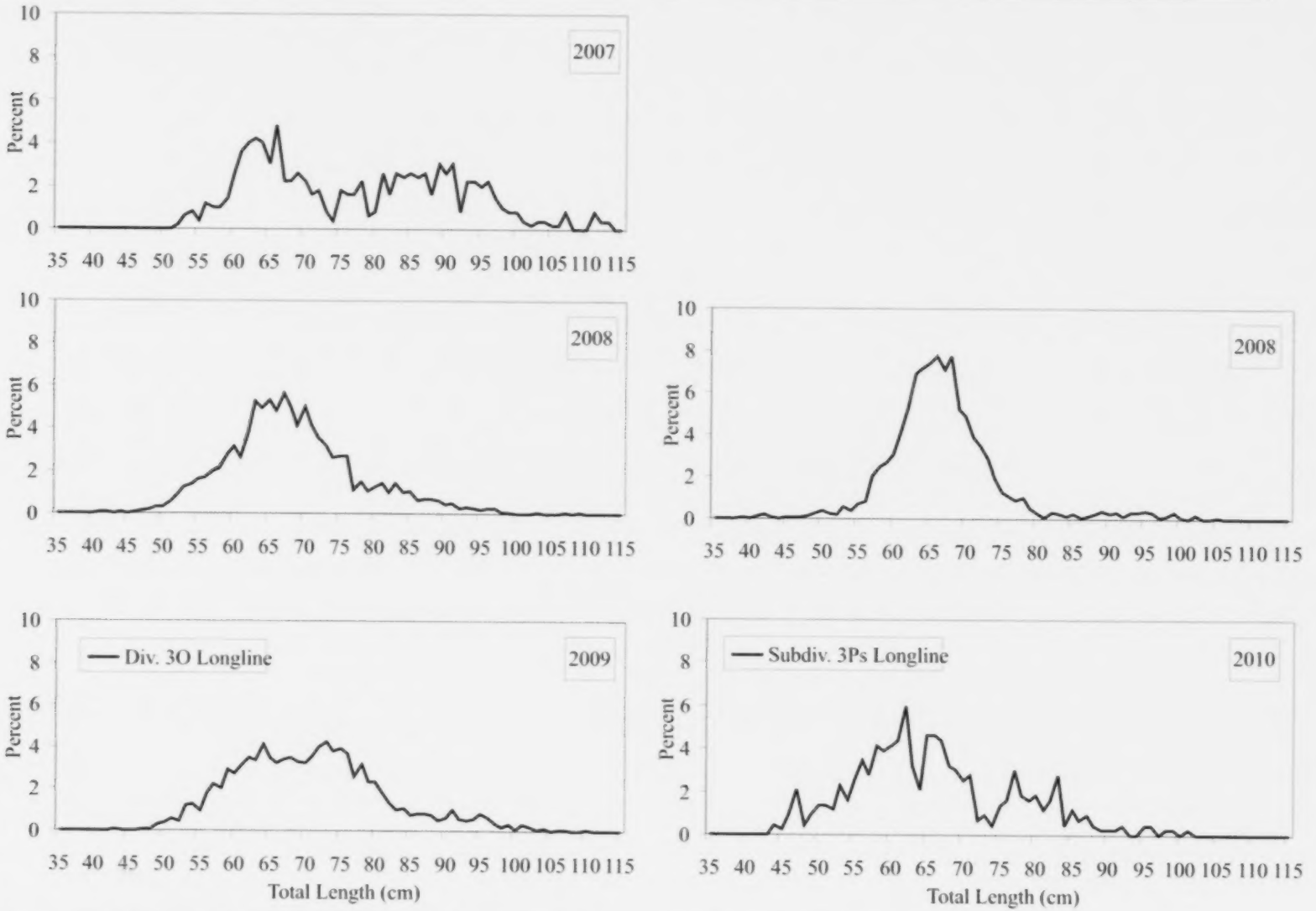

Figure 27b. Size of White Hake caught in NAFO Div. 3O and Subdiv. 3Ps by Canadian commercial longlines, 2007-2010. Data are from Canadian Fisheries Observers.

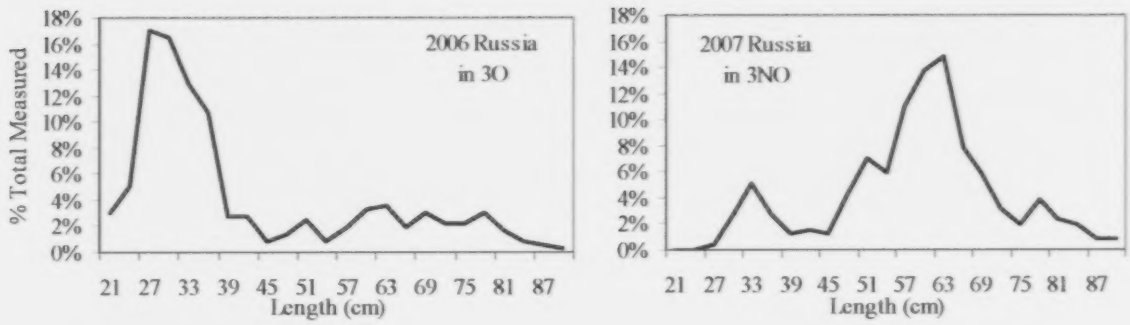

Figure 28. Available size frequency data for White Hake bycatch in Russian commercial trawl fisheries in the NAFO Regulatory Area, 2006-2010. Russia did not sample commercial White Hake in 2008, 2009, or 2010.

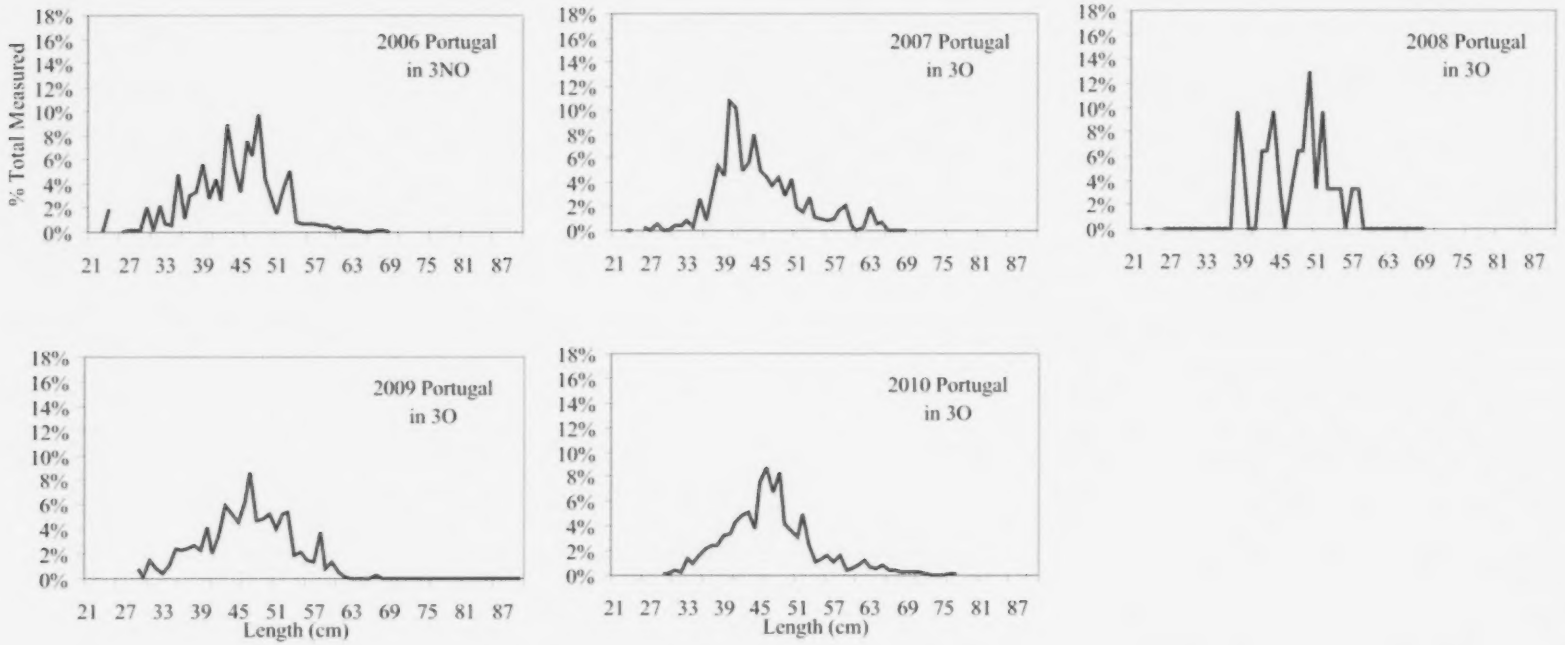

Figure 29. Available size frequency data for White Hake bycatch in EU-Portugal commercial trawl fisheries in the NAFO Regulatory Area, 2006-2010.

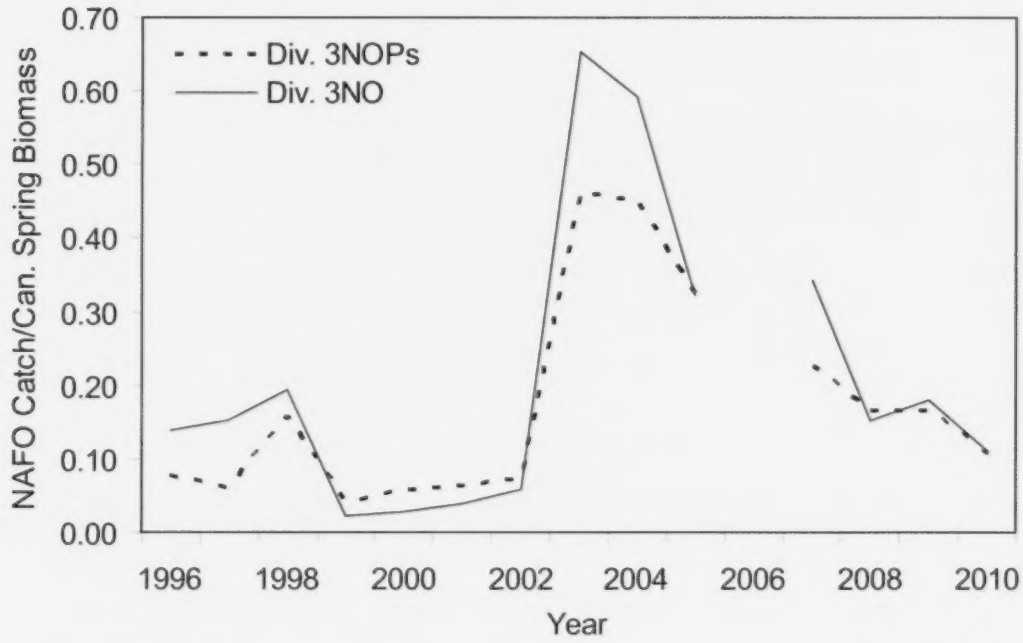

Figure 30. Relative F index (NAFO STATLANT-21A commercial catch/Canadian Campelen spring survey biomass) for White Hake in NAFO Div. 3NO and 3NOPs, 1996-2010. Note that deep strata in Div. 3NO and all of Subdiv. 3Ps were not surveyed in 2006; due to Canadian research vessels' mechanical difficulties.

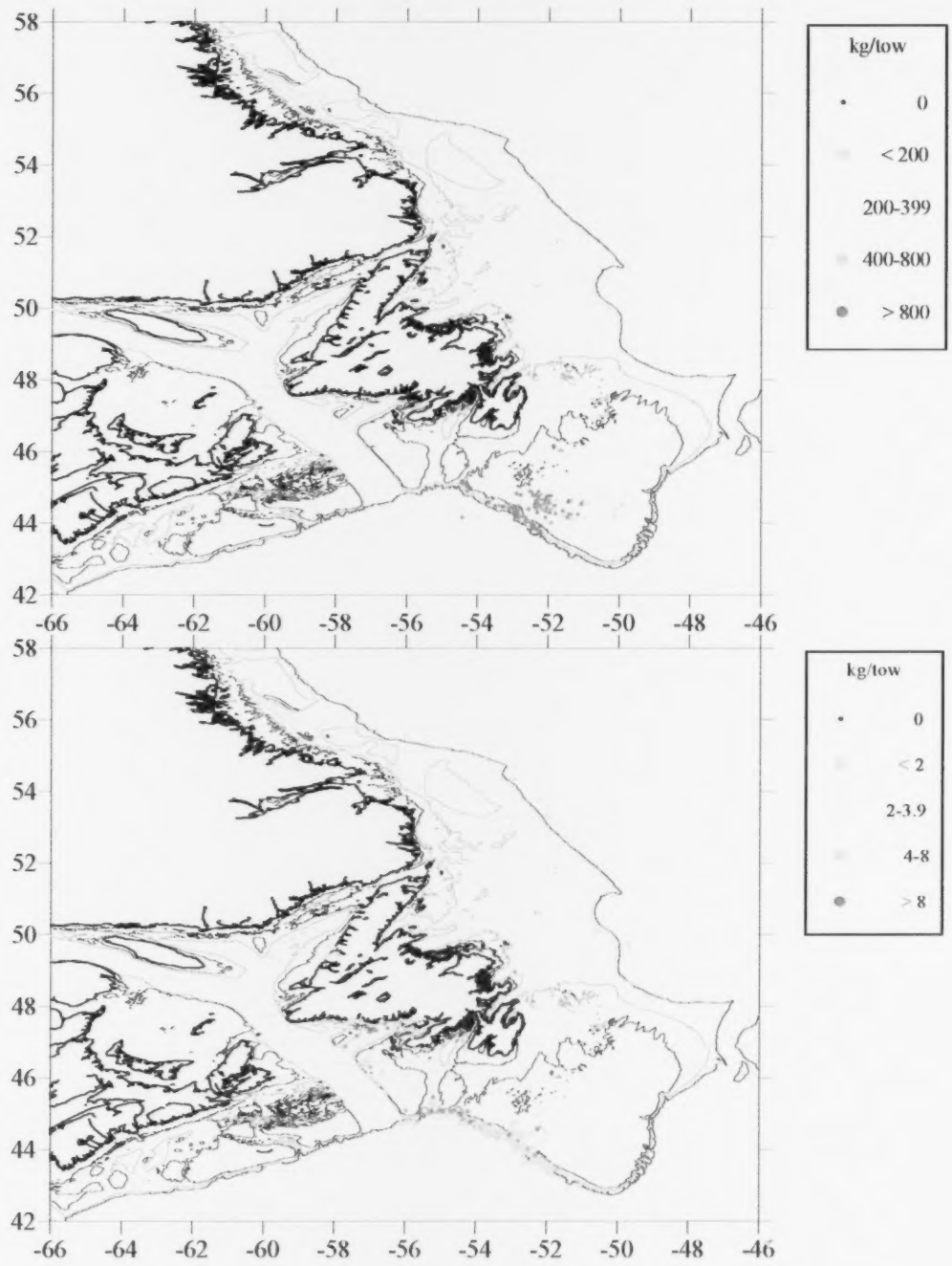

Figure 31. Catch per unit effort (CPUE) for White Hake in Canadian gillnet fisheries: Top Panel illustrates 1978 and 1981-1985; Bottom Panel shows 1988 and 1991-2011.

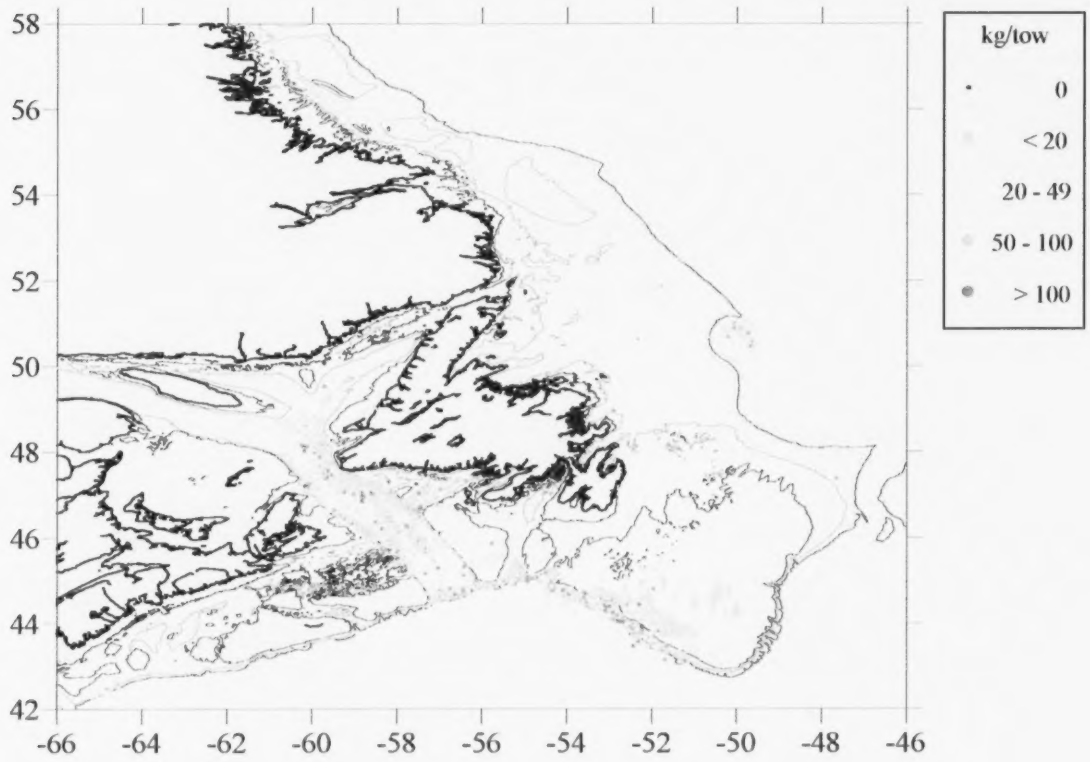

Figure 32. Catch per unit effort (CPUE) for White Hake in Canadian otter trawl fisheries, 1978-2011. The cluster of catches off the Northeast Newfoundland shelf are likely records of another Hake-like fish (Threebeard Rockling, see section on Commercial Fisheries Removals).